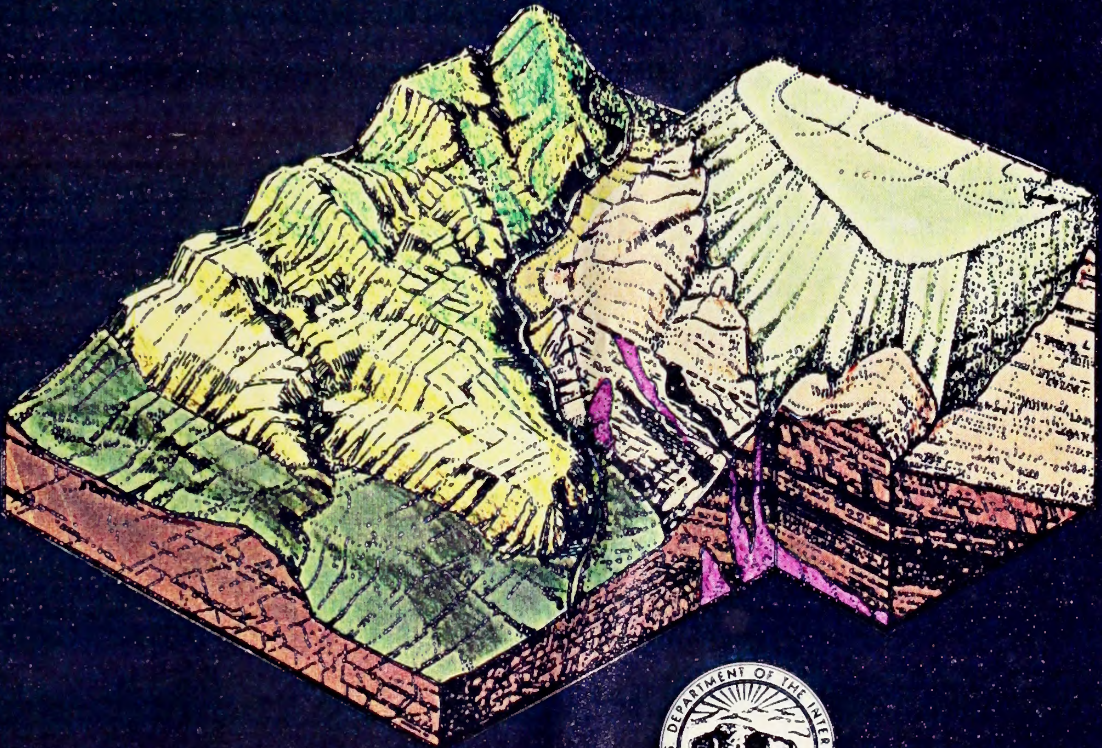
HYDROGEOLOGY AND EFFECTS OF MINE DUMP EXPANSION ON GROUND WATER QUALITY

BUTTERFIELD CANYON
SALT LAKE COUNTY, UTAH



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INTRODUCTION

The purpose of this report is to analyze the effects of expanded copper mine waste dumping on the ground water quality of the Butterfield Canyon area on the east side of the Bingham open-pit copper mine. The effects of natural leaching due to precipitation percolating through the mine dumps and into the ground water system will be addressed. Impacts of acid leaching are not addressed since that process is not part of the proposed action.

The study was designed to include a survey of relevant literature to the maximum extent possible, and field examination of the site to determine geology and general hydrogeologic character of the area. To accomplish this, a computerized literature data base was used, searching for various possible references using key words to retrieve data. Field work included measurement of water levels, evaluation of rock outcrops, sampling of water sources, and geologic reconnaissance of the area to determine extent of bedrock and valley fill deposits.

Previous Investigations

Work relating to geology of the study area has been done by several investigators beginning with Boutwell (1905) who studied the economic geology of the Bingham Mining District. Bissell (1959) studied the geology of the southern Oquirrh Mountains. Hunt (1924, 1933, 1963) studied the limestone ore deposits at Bingham and the distribution in the Lark District and at the U.S. Metals Mine. The geology and structure of the study area was studied and mapped by James, Smith and Welsh (1961). A road log describing the geology of the area in the vicinity of Lark and in roadcuts up Copper Gulch to the top of the mine area is described by Smith and James (1961). Welsh and James (1961) described the stratigraphy of the rocks in and near Butterfield Canyon.

Investigations into the hydrogeology of the Jordan Valley was first made by Richardson (1906), who evaluated the extent of aquifers and use of water in the Jordan Valley extending west to the Herriman and Lark areas. He included discussions of springs in Butterfield Canyon, the various tunnels constructed in the area for mining purposes, and the water the tunnels produced. Taylor and Leggette (1949) made a comprehensive study of the water resources of Jordan Valley which included the alluvial fill up to the bedrock of the Oquirrh and Traverse Mountains. Only one well was reported in the vicinity of the study area (near Herriman). Marine (1960) studied the geology and water resources of the Jordan Valley, and included several wells in the vicinity of Butterfield Canyon. Water quality analyses and water levels are presented. The Jordan Valley basin was subdivided by Marine (1961) into several districts using a classification scheme based in part on geomorphologic criteria; the study area here being classified in the south fan district. Mower (1969) also studied the ground water resources in Jordan Valley and included extensive geological assessments of the surrounding mountains.

The most comprehensive study of water resources in the area was made by Hely, Mower and Harr (1971) who made an exhaustive study of ground water quality and ground water use in Salt Lake County. This study included several wells in the vicinity of Lark and Herriman, near the study area.

Brimhall (1972) conducted column leaching studies on low-grade copper ores, and concluded that at pH values above 2.5-2.6, the leaching process comes to a halt. This study also discussed the activity of iron-reducing bacteria in the leaching process.

Auck (1973) provided data on the various chemical and physical factors involved in dump leaching of copper ore.

Geologic Setting

The area of the Nevada tract, and extending north for about 3/4 mile consists of exposures of the Butterfield Peaks Formation. Dikes of latite porphyry cut across the tract, generally trending northeast. These units make up the slopes on the west side of Butterfield Canyon. The east side of the canyon is composed of volcanic rocks, which include latite flows, latite breccias (with interbeds of tuff, sandstone and gravel) andesite flows, and latite tuff-breccia (Swenson, 1975 p. 37).

The Butterfield Peaks Formation (middle unit) is comprised of light to medium bluish-gray limestone, light gray to tan banded calcareous quartzites, and orthoquartzites. The upper portion is largely calcareous quartzite with interbeds of light to medium gray cherty limestone and calcareous sandstones (Swensen, 1975, p. 26). Field reconnaissance verified the extent of limestone over the particular area involved in this study.

Exposures northward from the limit of the Butterfield Peaks Formation (about one mile north of the Nevada tract) are preponderantly volcanic sequences similar to those existing on the east side of Butterfield Canyon. These units (latite breccia) commonly contain beds of sedimentary sands, gravels, and tuff, all water deposited (Swensen, 1975, p. 37). Additionally, slightly different mineralogic composition is found in some of the volcanics northward.

The limestone beds on the north end of the Nevada tract display dips ranging from 28° NW to 58° NW. Toward the south end of the tract, structural movement has locally folded the strata and beds in this area dip 30° north. Higher up on the hillside (off of the Nevada tract) the limestone beds dip 65° north. Further south, the beds again display dips of about 30° NW (Swensen, 1975, map).

The area has been subjected to several events of structural deformation that has resulted in extensive folding and faulting of the strata in the Bingham Mine area and in the surrounding strata. Transverse high angle faults and bedding plane faults are common. Fracturing in the limestones due to compressional folding is severe. Field evidence at all outcrops visited revealed numerous near-vertical fractures with low angle fractures and bedding plane fractures cutting across these. There was no evidence of massive unfractured limestone in any of the areas visited. Smith (1975, p. 41) characterized this area as a "structural crossroads" where two systems of high angle faults intersect at roughly right angles. So much folding, faulting, and fracturing occurred here that easy access was available to magmatic material and hydrothermal solutions to produce the rich mineralization found in the Bingham pit today. These compressional forces are discussed at length in Smith (1975, p. 44, 45).

Ground Water

Occurrence

Evidence for movement of ground water in the vicinity of Nevada tract is limited, since few drill holes exist on the parcel which would provide a detailed picture of the direction and magnitude of ground water flow. However, sufficient data is available to give substantial credence to the proposed direction of ground water flow.

In assessing the ground water flow in the study area, particular attention should be paid to the lithostratigraphic units in the area, the geologic history, and the hydraulic characteristics of the strata resulting from these aspects.

In order to accurately assess the ground water resource situation in the study area, the following flow factors must be determined: (1) where is ground water recharge occurring, (2) how is ground water moving through the system, and (3) where and how is ground water being discharged from the system? Concomitantly, quantity of water factors can also be evaluated on this basis. These factors will be discussed qualitatively here and quantitatively in a later section.

Recharge and Discharge

Ground water recharge in the natural system is provided through precipitation at the top of the existing mine dumps and on the ridges surrounding the mine pit which reach altitudes of 8500 to 9207 ft on the west side of the pit. Some water falling inside the mine will percolate downward into the flow system, although this will be a very small amount, since runoff water and ground water are transported out of the mine area via three tunnels at different elevations that trend north into Bingham Canyon. It is not known what volumes of water flow out of these dewatering tunnels.

Precipitation at the top of the mine dumps is reported to be about 22 in. At the ridgetops west of the mine, it is on the order of 30 in. It is estimated that about 3 in. of this enters the ground water system, based on a typical infiltration component into the groundwater system.

Ground Water Movement

Precipitation falling on the Butterfield Canyon area will percolate downward or run off into surface flow systems depending on the permeability of the soil and bedrock. In the vicinity of the Nevada tract, and extending westward and northward, infiltration rates will be relatively high because of the highly fractured character of the Butterfield Peaks Formation and the thin soil cover. The fractured nature of the strata will permit water to flow in direct response to the hydraulic gradient that slopes eastward into Jordan Valley, which is the driving force for ground water movement in

the study area. Flow should behave more like porous media flow than fracture-controlled flow due to the high density of joints and fractures that occur in several directions, and at several angles of dip.

Solution of the fracture system below the saturated zone has very likely enlarged the original openings so that the transmissivity of the limestone is favorable for substantial amounts of water to flow freely through the system. Examination of water level data (Hely, et al., 1971) in the alluvial fill east of the Oquirrh Mountains indicates ground water is being discharged into the valley fill. Analysis of hydraulic gradients in the area indicate movement eastward from the mountain front with a strong northward component toward Great Salt Lake.

Examination of water level data in the "foothills" area in and near the Nevada tract indicates that water is moving through the bedrock in this area, toward the Jordan Valley. Measurements made in the field during August, 1981, coupled with data from Kennecott, indicate a hydraulic gradient towards the east exists in the bedrock in and near the Nevada tract. Well No. 17, located at the north end of the tract, had a water surface elevation (in 1978) of 5780 ft (Kennecott Corp. data). Well No. P-233, located 4500 ft north of the Nevada tract, has a water surface elevation of about 5741 ft (August, 1981). Another well, P-228, measured in August, 1981, has a water surface elevation of 5771 ft. Well K-71 had a water level of about 5680 ft in August, 1981. Springs exist west of the tract at higher elevations. Water level data for several wells in the area are given in Table 1. (See water level elevations, Plate 2, and Table 1.)

Ground water moves outward from the Oquirrh Mountains into Jordan Valley mostly under the influence of the gradient between the Jordan River and the mountain front. This gradient is maintained by the elevation differences of the water surface in the area west of the Nevada tract (estimated elevation 6000 to 6200 ft) and the elevation of the water surface at the Jordan River (elevation 4300 ft). Although reliance must be placed on rather sparse data, it is clear that water is moving to the east. If the case were opposite, i.e., water flowing west into the pit, we would see water levels <u>decreasing</u> in elevation from the <u>east side</u> of the Nevada tract to the west side and beyond. This situation does not exist. Further, we would not expect to see such a steep gradient into the valley existing in the water level contours of Hely et al. (plate 1). These contours indicate that water is moving quite rapidly away from the Oquirrh Mountain front. Conceivably, the steep hydraulic gradient seen in the valley fill east of the Oquirrh mountain front could be caused by other factors such as very low transmissibility or thin aquifers in the valley fill, or the thinness of the total fill. These factors can be dismissed on the basis of suggestive evidence; the transmissibility of the valley fill for example, should be higher than that found in the Oquirrh Mountain block fracture system because there are several layers of well-sorted gravels within the valley fill.

RECORDS OF SELECTED WELLS IN THE VICINITY OF THE NEVADA TRACT

Well Number	Owner or User	Year Drilled	Depth of Well (feet)	Diameter (inches)	Altitude of Land-Surface Datum (feet)	Depth to Water Above (+) or Below (-) Land-Surface Datum (feet)	Date of Measurement
(C-3-2)							
4adb-1	Kennecott Copper Corp.	1944	1,200	20	5,130	-152.3	02/25/64
5aac-1	Kennecott Copper Corp. No. 2	1947	1,200	20	5,302	- 87	05/47
5acb-1	Kennecott Copper Corp. No. 3	1945	1,274	20, 12, 10	5,367	-139	07/45
5adb-1	Kennecott Copper Corp. No. 1	1945	1,200	20	5,320	-147.6	10/29/58
8ccd-1	L. A. Christensen	1937	270	6	5,460	-175	05/37
8cdc-2	Continental Oil Co.	1953	220	6	5,440	-179	08/53
16abd-1	G. B. Robbe	1937	215	6	5,175	-195	05/37
26ccc-1	J. S. Butterfield	1954	300	12	4,990	-200	12/54
27bdd-1	U. S. Smelting, Refining and Mining Co.	1945	355	6	5,045	-110	12/45
28cac-1	" "	1937	230	8	5,260	-162	07/37
28dbb-1	" "	1937	230	8	5,260	-142.6	02/27/64
29acc-1	" "	1942	325	15	5,430	-123	06/42
29dac-1	" "	1945	200	8	5,400		
32baa-1	J. A. Dumont	1956	360	4	5,480	- 65.4	04/15/57
32dbc-1	Herriman Irrigation Co.	1950	190	12	5,420	- 13 - 6.5	11/50 01/27/59
33cac-1	J. H. Dansie	1961	350	12	5,262	- 28.2	02/27/64
34daa-1	Herriman Pipeline and Development Co.	1955	615	12	5,020	-135	04/55
34dbd-1	Herriman Irrigation Co.	1961	365	12	5,061	-176.2	02/18/65
35abc-1	H. K. Bodell	1961	391	12	4,928	-196	06/25/61
35bdc-1	R. I. Bowlee	1954	269	8	4,980	-158	04/54

Table 1

The thickness of the valley fill does not appear to be a factor. Field data along with suggestive evidence does not indicate that the valley fill is excessively thin except perhaps locally. For example, a well drilled in the SWNWSE sec. 32, T. 3 S., R. 2 W., encountered bedrock at 185 feet. Another nearby well about one mile east, in sec. 33, encountered limestone bedrock at 336 feet; similarly, a well in SWSWNE sec. 29 encountered bedrock at 300 feet.

The thickness of fill near Lark is somewhat greater than given in Hely et al. (1971, p. 132) where the thickness is reported to be up to 200 feet. East of Lark, the fill increases up to 700 feet near Herriman. Northward east of Copperton, the fill is at least 1,000 feet thick according to drilling log of well (C3-2) 14bcd-1 (Iorns, et al., 1965, p 16).

Although the steep hydraulic gradient seen along the mountain front causes water to flow eastward at markedly faster rates than in the center of the valley (300 ft/mi vs 1 ft/mi), the thinner alluvial deposits along the mountain front controls the quantity of water moving outward. The aquifer is thinnest where hydraulic conductivity is highest and thickest where it is lowest so that the area of low velocity is capable of storing great amounts of water due to the much thicker aquifer sequence. The result is less areal variation in the quantity of water moving through the system than the examination of flow rates might suggest (Hely et al., 1971, p. 131).

Analysis of the water level contours in plate 1 of Hely et al. (1971) indicates that farther north, ground water movement in the valley is shifting northward under influence of the Great Salt Lake base level.

Ground water north of the Nevada tract will be moving eastward through bedrock and into the valley, but with a more pronounced north component influencing the flow system. Contour intervals shown on plate 1 of Hely et al. (1971) demonstrate this movement. It is important to note here because it helps to show that the valley fill is being partially recharged by discharge from the bedrock of the Oquirrh Mountains.

Infiltration and movement of ground water in areas north of the Nevada tract beyond the extent of the Butterfield Peaks Formation will necessarily be less substantial because of the decreased fracture density and the different rock types present in these areas, which are less permeable than the fractured limestone of the Butterfield Peaks Formation.

Ground Water Discharge

Ground water is being discharged from the system in the study area in the following ways:

(1) Discharge of springs located southwest of the tract, and in several areas west of the Nevada tract, at higher elevations.

(2) Discharge of water through abandonded mine tunnels such as Butterfield Tunnel (which flows into Butterfield Creek) Mascotte Tunnel (which flows into Keystone Gulch) and the Utah metals tunnel on the west side of the mountain.

(3) Flow through the fracture system directly into the alluvial fill of Jordan Valley.

(4) Discharge from the mine pit area through three drainage tunnels that feed into Bingham Creek.

(5) Discharge into volcanic rocks with ultimate discharge into the alluvium. This is principally flow through gravel deposits within the volcanics. Some flow occurs in fractures in the volcanics, but as a general matter, this rock type is relatively impermeable.

These various methods of discharge indicate that water is moving through the entire Oquirrh Mountain rock sequence in the vicinity of the mine pit and in the study area. Spring flows and water production from the tunnels reported by Richardson (1906) indicate that conditions have not changed appreciably since inception of mining operations (in 1905) as water was reported flowing in the various mine tunnels during their construction, and springs were described as flowing above Butterfield Creek.

Hely, et al. (1971, p. 121) made estimates of the total recharge moving from the Oquirrh Mountains through bedrock eastward to the Jordan Valley aquifer. The estimates were made utilizing two methods of computation, with weighting given to the high estimate because of geological conditions. Estimates are that 29,000 acre-feet per year of water (9,449,690,600 gal/year) are moving into the Jordan aquifer from the Oquirrh Mountains along a 25-mile line from the Traverse Mountains northward to the north end of the Oquirrh Mountains. The figure for recharge into the valley fill from the Oquirrh's may be as low as 20,000 acre-ft/yr (Hely et al., p. 121) based on the method of calculation using disposal of precipitation as described in Hely et al. (p. 174-177). Further analysis by the USGS suggests that the ground water seepage into the Jordan Valley may be as high as 34,000 acre-ft/yr (using Darcy's equation as a basis for calculation). Because of factors related to the geology of the Oquirrh Mountain block, the overall "best estimate" of recharge through bedrock is established at 29,000 acre-ft/yr. In contrast, an estimated 7,000 acre-ft are being provided from surface runoff from the Oquirrh Mountains (Hely et al., p. 97).

The precise figure for ground-water recharge is probably not as significant as the qualitative demonstration that (1) substantial amounts of water are moving through the Oquirrh Mountain block, and that (2) surface runoff constitutes a small percent of the total recharge to Jordan Valley from this area.

Quality of Water

Surface Water Quality

In evaluating the potential impacts of additional mine overburden placement to the ground water system, surface water quality may be used as an indicator. The surface water quality can be affected in two ways: (1) by runoff from the existing mine dumps, or (2) from contribution from ground water that has flowed through the mine dumps prior to entering the ground water system. A good indicator of the quality of surface water runoff would be to examine the quality of Butterfield Creek since this is where we could expect to notice some effect of contaminant transport from the mine area.

Water quality data pertaining to Butterfield Creek has been gathered from several sources, and is displayed in Table 2. From all data sources evaluated, the Creek doesn't currently exceed the Utah MCL's for TDS or SO_4.

The water quality data for Butterfield Creek are also significant in terms of dilution of TDS and SO_4 input from the Butterfield tunnel flow. Water issuing from the tunnel (Tables 2, 12e, 12f, 12g; site S-53 on plate 1) was above the Utah MCL for SO_4 at the beginning of record taking by Kennecott in 1969. These values dropped to below the standard in 1973 and have remained below the Utah MCL ever since.

Recent (August, 1981) data from BLM investigators show that the portal discharge is well below the Utah MCL for both TDS and SO_4 (Table 2). However, the values for both TDS and SO_4 from the portal have consistently been above the 1962 USPHS standards and the 1972 National Academy of Sciences standard of 500 mg/l for TDS and 250 mg/l for SO_4. Samples taken downstream from the portal show values for TDS and SO_4 that are well within the Utah MCL's for these constituents. Some dilution has occurred downstream, so that SO_4 is only slightly (25 to 30 mg/l) over the 1962 USPHS standard; TDS wasn't diluted to the same degree; values of TDS are around 700 mg/l throughout the reach of Butterfield Creek sampled.

Arsenic from the portal (Butterfield tunnel) is at 16 micrograms per liter (µg/l) which is .01 mg/l, and represents a "worst case" analysis of water near the Nevada tract. One other analysis showed high arsenic values. This was at a spring southwest of the Nevada tract near the old Queen mine (elev. 7250 ft). This spring had arsenic of 80 µg/l. These values are the highest values noted for arsenic in this study. At 80 µg/l, arsenic is still below the 1962 USPHS standard of .1 mg/l (80 µg/l = .08 mg/l), but is close to the value.

A Keystone Gulch surface water sampling site was reported in Price (1981) to contain water exceeding the recommended 1962 Drinking Water Standards (see Table 2). This drainage, however, contains water originating north of the Nevada tract, from the Lark area, and from the Mascotte Tunnel

CHEMICAL ANALYSES OF SELECTED CREEKS IN THE VICINITY OF THE NEVADA TRACT

Stream or Canal	Location of Collection Point	Date of Collection	Temperature (^{o}F)	Parts Per Million														Percent Sodium	Sodium Absorption Ratio (SAR)	Specific Conductance (micromhos/cm at 25°C)	PH
				Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Na + K: Sodium (Na)	Na + K: Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids 1/	Hardness as $CaCO_3$	Noncarbonate Hardness as CaCO3				
Butterfield Creek	SE¼SW¼ sec. 31, T. 3S R. 2W, 0.7 mile upstream from Utah Hwy. 111 and 3.6 miles SW of Herriman	4/3/64	50																	1,190	
		4/15/64	58																	1,210	
		5/6/64	52																	1,090	
		5/22/64	62																	835	
		5/29/64	49																	1,010	
		6/26/64	60																	1,340	
		7/30/64	57																	1,450	
Butterfield Creek	" "	10/30/64	50																	1,440	
		5/14/65	52	4.2		147	.70	38		186	516	34		1.7	935	656	503		.6	1,210	8.0
Butterfield Creek	Above Butterfield Tunnel	9/08/65	54	16		67	18	44		310	35	34		.9	364	243	0		1.2	591	8.1
Butterfield Tunnel		9/08/65	56	9.4		226	102	34		136	877	25		.1	1,340	985	873		.5	1,630	7.4
Butterfield Creek (S-1)	T4S, R3W, Sec. 11, NESW	08/17/81		14		67	29	29	2	320	52	20	.15	.45	353	288	262			600	
Butterfield Creek (S-2)N	T4S, R2W, Sec. 6, SWSW	08/17/81		19		72	21	22	2	284	40	24	.66	.37	336	266	239			553	
Butterfield Creek (S-2)H	Above Mine Portal	08/10/81		9		51	8	8	5	155	53	11	.15	.12	236	168	124			364	
Butterfield Creek (S-3)H	Below Mine Portal	08/10/81		10		154	32	9	6	140	405	12	.19	.45	742	525	115			948	
Butterfield Creek (S-3)N	T4S, R2W, Sec. 6, SWSW	08/17/81		20		138	41	23	3	280	274	30	.40	.29	704	515	230			970	
Butterfield Creek (S-4)	T4S, R2W, Sec. 6, NWNE	08/17/81		20		136	39	25	3	260	277	32	.43	.14	702	500	230			962	
Butterfield Creek (S-5)	T3S, R2W, Sec. 32, NESW	08/17/81		20		138	41	26	2	264	277	40	.43	.21	728	615	233			988	
Keystone Gulch	T3S, R2W, Sec. 28, SENENW	05/14/65		20		216	96	60	-	20	920	65	-	1.5	1,390	935	919		.9	1,660	6.9

Table 2

(abandoned). Water from the Mascotte tunnel is not the result of the Kennecott mining operation, but does represent a source of potential pollutants exceeding the Utah MCL's. Water from this source also enters Butterfield Creek in SW1/4 sec. 33, T. 3 S., R. 2 W. The analysis at site S-21B shows water quality has been above the Utah MCL for TDS and SO_4. However, the most recent sample shows values below the Utah MCL for both constituents. Monitoring of this site should continue, but with an increased frequency.

Further information relating to the quality of existing ground water drinking supplies is seen in data from the Utah Department of Health (Bousfield, 1981), who provided chemical analyses of samples taken in the vicinity of the study area, including the Lark, Copperton and Hi-country Estates systems (Tables 3 through 11). Note that values of TDS and SO_4 are all within the Utah MCL standards, though some could be described as marginal (i.e., concentrations of TDS or SO_4 exceeding the 1962 USPHS recommended standard, but under the Utah MCL).

The Lark water supply utilizes Willow spring which is just below the Yosemite dump. Samples from this source have been consistently higher than the 1962 standard for TDS and SO_4. Although not hazardous to health at these levels, further increase over time in these constituents could render the source unusable because of taste and laxative effects.

The hardness of the water is also quite high, but in the expected range for waters in contact with limestone.

Ground Water Quality

Of primary concern in this study is the impact and potential impact of placing large amounts of copper mine overburden in gulches above (west of) the Nevada tract, and for approximately one mile northwestward (resulting from expansion, north to south, of the Yosemite, Saints Rest, Castro and Olsen mine dumps). The impacts of increased scale mine dumps at these sites will primarily affect Parcel Number 31 (the Nevada tract) and Parcel No. 10 (the 390 acre parcel extending south and southwest of the southernmost extension of the Nevada tract). Expansion of the Yosemite Dump will not affect BLM-administered lands directly, but may have an impact on the ground water resource.

The mine dumps presently consist predominantly of limestone and quartzite. The composition of the above-named dumps is as follows (data from Kennecott):

Dump	%Intrusive	%Limestone	%Quartzite	%Fill Material
Yosemite	20	19	43	18
Saints Rest	7	28	58	7
Castro	16	19	55	10
Olsen	13	25	60	2

CHEMICAL ANALYSIS

LABORATORY NUMBER: F778081 LABORATORY: FORD LABORATORY

SYSTEM INFORMATION	SAMPLE COLLECTION	SAMPLING LOCATION	SEND REPORT TO
SYSTEM NAME: HI-COUNTRY ESTATES	DATE : 11/17/77	NEW WELL TO SERVE HI	SALT LAKE CO WD
SYSTEM NO. : 18009	TIME : 09:45	COUNTRY ESTATES (JES	AND HI COUNTRY ESTAT
SOURCE NO. : 02	BY : T HOLZWORTH	SE DANSIE WELL)	ES
SOURCE TYPE: WELL	PHONE: —		

CATIONS	MG/L	UG/L	ANIONS	MG/L	TOTAL METALS-CATIONS	MG/L	UG/L
AMMONIA AS N:	.		BICARBONATE:	325.	ARSENIC:		.
ARSENIC:		.0	CARBON DIOXIDE:	.	BARIUM:	.	
BARIUM:		40.0	CARBONATE:	0.	CADMIUM:		
BORON:		110.0	CHLORIDE:	98.	CHROMIUM:		.
CADMIUM:		.0	CO3 SOLIDS:	.	COPPER:		.
CALCIUM:	155.		FLUORIDE:	.19	IRON:	.57	
CHROMIUM:		.0	HYDROXIDE:	.0	LEAD:		.
CHROMIUM, HEX AS CR:		.0	NITRATE AS N:	1.28	MANGANESE:		.
COPPER:		.0	NITRITE AS N:	.0	MERCURY:		.0
IRON, DISSOLVED:		150.0	PHOSPHORUS (I AS P:	.	NICKEL:		.
LEAD:		.0	SILICA, DIS. SIO2:	32.	SELENIUM:		.
MAGNESIUM:	36.		SULFATE:	220.	SILVER:		.
MANGANESE:		3.0			URANIUM:		.
NICKEL:		.0	TOT. ALK. AS CACO3:	266.	ZINC:		.
POTASSIUM:	5.		T. HDNS. CACO3:	540.0			
SELENIUM:		.0	SURFACTANT AS MBAS:	.0			
SILVER:		.0	TURBIDITY:	.2	OTHER:		
SODIUM:	40.		SP COND UMHOS/CM:	1110		:	:
ZINC:		10.0	TDS @ 180'C:	715			

SPECIAL WATER ANALYSIS

T. K. N.: PH: 7.6 T. O. C.: . OTHER: :

Table 3

CHEMICAL ANALYSIS

LABORATORY NUMBER: C804533 LABORATORY: STATE HEALTH

SYSTEM INFORMATION		SAMPLE COLLECTION		SAMPLING LOCATION	SEND REPORT TO
SYSTEM NAME:	HI-COUNTRY ESTATES	DATE :	10/08/80	TAP ON LAWN. WELL O	J.W. DANSIE
SYSTEM NO. :	18009	TIME :	08:00	WNED BY J. W. DANSIE	P.O. BOX 150
SOURCE NO. :	02	BY :	J.W. DANSIE	. (DANSIE WELL)	SPANISH FK. UT
SOURCE TYPE:	WELL	PHONE:	873-2596		84660

CATIONS	MG/L	UG/L	ANIONS	MG/L	TOTAL METALS-CATIONS	MG/L	UG/L
AMMONIA AS N:	<0.1		BICARBONATE:	344.	ARSENIC:		11.
ARSENIC:		.	CARBON DIOXIDE:	3.	BARIUM:	<0.05	
BARIUM:		.	CARBONATE:	0.	CADMIUM:		<1
BORON:		265.0	CHLORIDE:	42.	CHROMIUM:		<5.
CADMIUM:		.	CO3 SOLIDS:	169.	COPPER:		<10.
CALCIUM:	44.		FLOURIDE:	.43	IRON:	0.09	
CHROMIUM:		.	HYDROXIDE:	0.00	LEAD:		<10.
CHROMIUM, HEX AS CR:		<5.0	NITRATE AS N:	2.00	MANGANESE:		<10.
COPPER:		.	NITRITE AS N:	<0.05	MERCURY:		0.1
IRON, DISSOLVED:		.	PHOSPHORUS O AS P:	<0.02	NICKEL:		20.
LEAD:		.	SILICA, DIS. SIO2:	25.	SELENIUM:		<1.
MAGNESIUM:	46.		SULFATE:	195.	SILVER:		<2.
MANGANESE:		.			URANIUM:		.
NICKEL:		.	TOT. ALK. AS CACO3:	282.	ZINC:		50.
POTASSIUM:	3.		T. HDNS. CACO3:	300.0			
SELENIUM:		.	SURFACTANT AS MBAS:	.			
SILVER:		.	TURBIDITY:	0.1	OTHER:		
SODIUM:	83.		SP COND UMHOS/CM:	1000			
ZINC:		.	TDS @ 180'C:	546			

SPECIAL WATER ANALYSIS

T. K. N.:		PH:	8.2	T. O. C.:	.	OTHER:	:

Table 4

C H E M I C A L   A N A L Y S I S

LABORATORY NUMBER: F708415 LABORATORY: FORD LABORATORY

- - SYSTEM INFORMATION- -	- - SAMPLE COLLECTION- -	-SAMPLING LOCATION -	- -SEND REPORT TO- -
SYSTEM NAME: HI-COUNTRY ESTATES	DATE : 01/25/78	HI COUNTRY WELL NO 1'	HI COUNTRY ESTATES
SYSTEM NO. : 18009	TIME : 15:00	FROM WELL HEAD TAP	PO BOX 14
SOURCE NO. : 01	BY : ROD DANSIE	(GLAZIER WELL)	RIVERTON UT 840
SOURCE TYPE: WELL	PHONE: --		65

- - - - - -C A T I O N S- - - - - -	MG/L	UG/L	- - - - -A N I O N S- - - - -	MG/L	- TOTAL METALS-CATIONS- -	MG/L	UG/L
AMMONIA AS N:	.		BICARBONATE:	206.	ARSENIC:		.
ARSENIC:		'.0	CARBON DIOXIDE:	.	BARIUM:	.	
BARIUM:		90.0	CARBONATE:	0.	CADMIUM:		
BORON:		50.0	CHLORIDE:	150.	CHROMIUM:		.
CADMIUM:		.0	CO3 SOLIDS:	.	COPPER:		.
CALCIUM:	110.		FLUORIDE:	.33	IRON:	.15	
CHROMIUM:		.0	HYDROXIDE:	. 0	LEAD:		.
CHROMIUM, HEX AS CR:		.0	NITRATE AS N:	1.00	MANGANESE:		.
COPPER:		4.0	NITRITE AS N:	. 0	MERCURY:		.0
IRON, DISSOLVED:		102.0	PHOSPHORUS O AS P:	.	NICKEL:		.
LEAD:		.0	SILICA, DIS. SIO2:	4.	SELENIUM:		.
MAGNESIUM:	27.		SULFATE:	72.	SILVER:		.
MANGANESE:		.0			URANIUM:		.
NICKEL:		.0	TOT. ALK. AS CACO3:	234.	ZINC:		.
POTASSIUM:	3.		T. HDNS. CACO3:	390.0			
SELENIUM:		.0	SURFACTANT AS MBAS:	. 0			
SILVER:		.0	TURBIDITY:	1.5	OTHER:		
SODIUM:	63.		SP COND UMHOS/CM:	886		:	:
ZINC:		49.0	TDS @ 180'C:	575			

S P E C I A L   W A T E R   A N A L Y S I S

T. K. N.:	PH: 7.3	T. O. C.: .	OTHER: :

Table 5

CHEMICAL ANALYSIS

LABORATORY NUMBER: C790047 LABORATORY: STATE HEALTH

SYSTEM INFORMATION		SAMPLE COLLECTION		SAMPLING LOCATION	SEND REPORT TO
SYSTEM NAME:	Lark Water Users	DATE :	01/22/79	WILLOW SPRING	
SYSTEM NO. :	18128	TIME :	13:00		
SOURCE NO. :	01	BY :	ROBERT PETERSON		
SOURCE TYPE:	SPRING	PHONE:	-		

CATIONS	MG/L	UG/L	ANIONS	MG/L	TOTAL METALS-CATIONS	MG/L	UG/L
AMMONIA AS N:	<0.1		BICARBONATE:	304.	ARSENIC:		4.0
ARSENIC:		.	CARBON DIOXIDE:	15.	BARIUM:	<0.05	
BARIUM:		.	CARBONATE:	0.	CADMIUM:		<5
BORON:		<50.0	CHLORIDE:	126.	CHROMIUM:		<10.0
CADMIUM:		.	CO3 SOLIDS:	189.	COPPER:		10.0
CALCIUM:	176.		FLOURIDE:	.22	IRON:	0.0<	
CHROMIUM:		.	HYDROXIDE:	. 0	LEAD:		<20.0
CHROMIUM, HEX AS CR:		<5.0	NITRATE AS N:	1.95	MANGANESE:		<5.0
COPPER:		.	NITRITE AS N:	<0.05	MERCURY:		<0.1
IRON, DISSOLVED:		.	PHOSPHORUS O AS P:	0.05	NICKEL:		<25.0
LEAD:		.	SILICA, DIS. SIO2:	19.	SELENIUM:		<0.5
MAGNESIUM:	54.		SULFATE:	330.	SILVER:		<5.0
MANGANESE:		.			URANIUM:		.
NICKEL:		.	TOT. ALK. AS CACO3:	315.	ZINC:		65.0
POTASSIUM:	3.		T. HDNS. CACO3:	660.0			
SELENIUM:		.	SURFACTANT AS MBAS:	<0.03			
SILVER:		.	TURBIDITY:	<0.2	OTHER:		
SODIUM:	71.		SP COND UMHOS/CM:	1460			
ZINC:		.	TDS @ 180'C:	980			

SPECIAL WATER ANALYSIS

T. K. N.: PH: 7.6 T. O. C.: OTHER:

Table 6

C H E M I C A L   A N A L Y S I S

LABORATORY NUMBER: C011352   LABORATORY: STATE HEALTH

- - - - - - SYSTEM INFORMATION- - - - - -	- - - SAMPLE COLLECTION- - -	-SAMPLING LOCATION -	- -SEND REPORT TO- -
SYSTEM NAME: LARK WATER USERS	DATE : 04/13/81	LARK WATER USERS: DI	LARK WATER USERS
SYSTEM NO. : 18128	TIME : 12:00	ST. SYS. @ ROBERT PE	ROBERT PETERSON LARK
SOURCE NO. :	BY : ROBERT PETERSON	TERSON HOME TUB.	UT 0555W12600S
SOURCE TYPE: DISTRIB SYSTEM	PHONE: 934-2428		84065

- - - - - -C A T I O N S- - - - - -	MG/L	UG/L	- - - - -A N I O N S- - - - -	MG/L	- TOTAL METALS-CATIONS- -	MG/L	UG/L
AMMONIA AS N:	<0.1		BICARBONATE:	202.	ARSENIC:		3.
ARSENIC:		.	CARBON DIOXIDE:	3.	BARIUM:	<0.05	
BARIUM:		.	CARBONATE:	0.	CADMIUM:		<1
BORON:		125.0	CHLORIDE:	150.	CHROMIUM:		<5.
CADMIUM:		.	CO3 SOLIDS:	99.	COPPER:		15.
CALCIUM:	156.		FLUORIDE:	.15	IRON:	0.28	
CHROMIUM:		.	HYDROXIDE:	0.00	LEAD:		<5.
CHROMIUM, HEX AS CR:		<5.0	NITRATE AS N:	1.92	MANGANESE:		<10.
COPPER:		.	NITRITE AS N:	<0.05	MERCURY:		<0.1
IRON, DISSOLVED:		.	PHOSPHORUS O AS P:	0.05	NICKEL:		<10.
LEAD:		.	SILICA, DIS. SIO2:	5.	SELENIUM:		<1.
MAGNESIUM:	44.		SULFATE:	281.	SILVER:		<2.
MANGANESE:		.			URANIUM:		.
NICKEL:		.	TOT. ALK. AS CACO3:	166.	ZINC:		210.
POTASSIUM:	3.		T. HDNS. CACO3:	570.0			
SELENIUM:		.	SURFACTANT AS MBAS:	.			
SILVER:		.	TURBIDITY:	1.0	OTHER:		
SODIUM:	46.		SP COND UMHOS/CM:	1290			
ZINC:		.	TDS @ 180'C:	876			

S P E C I A L   W A T E R   A N A L Y S I S

T. K. N.:   PH: 8.1   T. O. C.:   OTHER:

Table 7

CHEMICAL ANALYSIS

LABORATORY NUMBER: F788481 LABORATORY: FORD LABORATORY

SYSTEM INFORMATION		SAMPLE COLLECTION		SAMPLING LOCATION	SEND REPORT TO
SYSTEM NAME:	COPPERTON IMPROVMNT DIST.	DATE :	01/13/70	DEEP WELL PUMP #3	
SYSTEM NO. :	18005	TIME :	10:00		
SOURCE NO. :	02	BY :	MILNER		
SOURCE TYPE:	WELL	PHONE:	774-2595		

CATIONS	MG/L	UG/L	ANIONS	MG/L	TOTAL METALS-CATIONS	MG/L	UG/L
AMMONIA AS N:	.		BICARBONATE:	229.	ARSENIC:		.
ARSENIC:		2.0	CARBON DIOXIDE:	.	BARIUM:	.	
BARIUM:		5.0	CARBONATE:	0.	CADMIUM:		
BORON:		50.0	CHLORIDE:	152.	CHROMIUM:		.
CADMIUM:		.0	CO3 SOLIDS:	.	COPPER:		.
CALCIUM:	89.		FLUORIDE:	.28	IRON:	.15	
CHROMIUM:		5.0	HYDROXIDE:	. 0	LEAD:		.
CHROMIUM, HEX AS CR:		.0	NITRATE AS N:	1.14	MANGANESE:		.
COPPER:		29.0	NITRITE AS N:	. 0	MERCURY:		.0
IRON, DISSOLVED:		111.0	PHOSPHORUS O AS P:	.	NICKEL:		.
LEAD:		.0	SILICA, DIS. SIO2:	55.	SELENIUM:		.
MAGNESIUM:	37.		SULFATE:	30.	SILVER:		.
MANGANESE:		21.0			URANIUM:		.
NICKEL:		.0	TOT. ALK. AS CACO3:	108.	ZINC:		.
POTASSIUM:	4.		T. HDNS. CACO3:	378.0			
SELENIUM:		.0	SURFACTANT AS MBAS:	. 0			
SILVER:		.0	TURBIDITY:	1.1	OTHER:		
SODIUM:	22.		SP COND UMHOS/CM:	92		:	:
ZINC:		91.0	TDS @ 180'C:	449			

SPECIAL WATER ANALYSIS

T. K. N.: PH: 7.9 T. O. C.: . OTHER: :

Table 8

CHEMICAL ANALYSIS

LABORATORY NUMBER: F788482 LABORATORY: FORD LABORATORY

SYSTEM INFORMATION		SAMPLE COLLECTION		SAMPLING LOCATION	SEND REPORT TO
SYSTEM NAME:	COPPERTON IMPROVMNT DIST.	DATE :	01/13/78	DEEP WELL PUMP #2	
SYSTEM NO. :	18005	TIME :	10:30		
SOURCE NO. :	01	BY :	MILNER		
SOURCE TYPE:	WELL	PHONE:	774-2595		

CATIONS	MG/L	UG/L	ANIONS	MG/L	TOTAL METALS-CATIONS	MG/L	UG/L
AMMONIA AS N:	.		BICARBONATE:	215.	ARSENIC:		.
ARSENIC:		4.0	CARBON DIOXIDE:	.	BARIUM:	.	
BARIUM:		8.0	CARBONATE:	0.	CADMIUM:		
BORON:		50.0	CHLORIDE:	144.	CHROMIUM:		.
CADMIUM:		.0	CO3 SOLIDS:	.	COPPER:		.
CALCIUM:	82.		FLUORIDE:	.32	IRON:	.13	
CHROMIUM:		7.0	HYDROXIDE:	.0	LEAD:		.
CHROMIUM, HEX AS CR:		.0	NITRATE AS N:	1.14	MANGANESE:		.
COPPER:		66.0	NITRITE AS N:	.0	MERCURY:		.0
IRON, DISSOLVED:		96.0	PHOSPHORUS O AS P:	.	NICKEL:		.
LEAD:		.0	SILICA, DIS. SIO2:	60.	SELENIUM:		.
MAGNESIUM:	33.		SULFATE:	20.	SILVER:		.
MANGANESE:		10.0			URANIUM:	.	.
NICKEL:		.0	TOT. ALK. AS CACO3:	176.	ZINC:		.
POTASSIUM:	5.		T. HDNS. CACO3:	344.0			
SELENIUM:		.0	SURFACTANT AS MBAS:	.0			
SILVER:		.0	TURBIDITY:	1.9	OTHER:		
SODIUM:	22.		SP COND UMHOS/CM:	640		:	:
ZINC:		120.0	TDS @ 180'C:	415			

SPECIAL WATER ANALYSIS

T. K. N.: PH: 8. T. O. C.: . OTHER: :

Table 9

CHEMICAL ANALYSIS

LABORATORY NUMBER: F788587 LABORATORY: FORD LABORATORY

SYSTEM INFORMATION		SAMPLE COLLECTION		SAMPLING LOCATION	SEND REPORT TO
SYSTEM NAME:	KENNECOTT COPPER CO	DATE :	05/04/78	KITCHEN TAP AT COPPE	
SYSTEM NO. :	18003	TIME :	10:30	R COUNTRY CLUB	
SOURCE NO. :	01	BY :	KEN BOUSFIELD		
SOURCE TYPE:	WELL	PHONE:	322-1533		

CATIONS	MG/L	UG/L	ANIONS	MG/L	TOTAL METALS-CATIONS	MG/L	UG/L
AMMONIA AS N:	.		BICARBONATE:	320.	ARSENIC:		.
ARSENIC:		35.0	CARBON DIOXIDE:	.	BARIUM:	.	
BARIUM:		140.0	CARBONATE:	<1.	CADMIUM:		
BORON:		320.0	CHLORIDE:	532.	CHROMIUM:		.
CADMIUM:		<1.0	CO3 SOLIDS:	.	COPPER:		.
CALCIUM:	65.		FLUORIDE:	.60	IRON:	. 5	
CHROMIUM:		<1.0	HYDROXIDE:	<.01	LEAD:		.
CHROMIUM, HEX AS CR:		<1.0	NITRATE AS N:	3.50	MANGANESE:		.
COPPER:		8.0	NITRITE AS N:	<.01	MERCURY:		<.2
IRON, DISSOLVED:		<50.0	PHOSPHORUS O AS P:	.	NICKEL:		.
LEAD:		46.0	SILICA, DIS. SIO2:	47.	SELENIUM:		.
MAGNESIUM:	31.		SULFATE:	232.	SILVER:		.
MANGANESE:		17.0			URANIUM:		.
NICKEL:		<1.0	TOT. ALK. AS CACO3:	262.	ZINC:		.
POTASSIUM:	18.		T. HDNS. CACO3:	292.0			
SELENIUM:		6.0	SURFACTANT AS MBAS:	.15			
SILVER:		<1.0	TURBIDITY:	.3	OTHER:		
SODIUM:	430.		SP COND UMHOS/CM:	2250			
ZINC:		100.0	TDS @ 180'C:	1460			

SPECIAL WATER ANALYSIS

T. K. N.: PH: 7.4 T. O. C.: . OTHER: :

Table 10

CHEMICAL ANALYSIS

LABORATORY NUMBER: F788584 — LABORATORY: FORD LABORATORY

SYSTEM INFORMATION		SAMPLE COLLECTION		SAMPLING LOCATION	SEND REPORT TO
SYSTEM NAME:	KENNECOTT COPPER CO	DATE :	05/04/78	KITCHEN TAP IN HOME	
SYSTEM NO. :	10003	TIME :	11:00	IN BINGHAM CANYON ON	
SOURCE NO. :	01	BY :	KEN BOUSFIELD	KENNECOTT SYSTEM	
SOURCE TYPE:	SPRING	PHONE:	322-1533		

CATIONS	MG/L	UG/L	ANIONS	MG/L	TOTAL METALS-CATIONS	MG/L	UG/L
AMMONIA AS N:	.		BICARBONATE:	317.	ARSENIC:		.
ARSENIC:		14.0	CARBON DIOXIDE:	. .	BARIUM:	.	
BARIUM:		130.0	CARBONATE:	<1.	CADMIUM:		
BORON:		110.0	CHLORIDE:	94.	CHROMIUM:		.
CADMIUM:		<1.0	CO3 SOLIDS:	.	COPPER:		.
CALCIUM:	93.		FLUORIDE:	.11	IRON:	.12	
CHROMIUM:		<1.0	HYDROXIDE:	<.01	LEAD:		.
CHROMIUM, HEX AS CR:		<1.0	NITRATE AS N:	. 8	MANGANESE:		.
COPPER:		12.0	NITRITE AS N:	<.01	MERCURY:		<.2
IRON, DISSOLVED:		<50.0	PHOSPHORUS O AS P:	.	NICKEL:		.
LEAD:		<1.0	SILICA, DIS. SIO2:	13.	SELENIUM:		.
MAGNESIUM:	35.		SULFATE:	116.	SILVER:		.
MANGANESE:		12.0			URANIUM:		.
NICKEL:		<1.0	TOT. ALK. AS CACO3:	260.	ZINC:		.
POTASSIUM:	1.		T. HDNS. CACO3:	376.0			
SELENIUM:		<1.0	SURFACTANT AS MBAS:	<.05			
SILVER:		3.0	TURBIDITY:	.2	OTHER:		
SODIUM:	60.		SP COND UMHOS/CM:	850		:	
ZINC:		45.0	TDS @ 180°C:	550			

SPECIAL WATER ANALYSIS

T. K. N.:		PH:	7.4	T. O. C.:	.	OTHER:	:

Table 11

The projected composition of the mine dumps based on computer analysis of future mine expansion is as follows:

Dump	%Intrusive	%Limestone	%Quartzite	%Fill Material
Yosemite-Saints Rest	21	18	53	8
Castro-Olsen	19	20	54	7

Ground water contamination that might result from these overburden piles (absent active leaching with acid) is the leachate produced when precipitation percolates down through the dump, dissolving constituents in the rock, and passing into the saturated zone (25-100 feet below the surface of the bedrock in this area).

In mined areas containing substantial amounts of alkaline rocks (such as limestone and calcareous quartzite existing in the study area), the dissolution effects of precipitation ordinarily produce water of high pH. Water of this character usually contains a low amount of heavy metals due to the fact that most heavy metals form insoluble salts under condition of high pH. Calcium and magnesium ions are commonly found in high concentrations (Miller, 1980 p. 328). At the Kennecott Mine dumps, significant amounts of sulfates are also likely produced, resulting from the oxidation of pyrite (FeS_2) in the presence of water, forming sulfuric acid and ferrous sulfate as seen in the following discussion.

The oxidation of sulfide minerals (pyrite or chalcopyrite for example) in a mine dump leaves limonite or hematite and generates sulfuric acid. The normal reaction involved is the following:

$$2FeS_2+\frac{15}{2}O_2+4H_2O \quad Fe_2O_3+4SO_4^{-3}+8H$$

(Park and MacDiarmid, 1964, p. 417).

This process of limonite and hematite deposition is confirmed by exploratory drilling performed by Kennecott (Kennecott, supplemental Assessment, 1981, p. 18). As can be seen in this equation, oxygen is required to drive the process. Ferric sulfate and sulfuric acid generated by the oxidation of iron sulfides (pyrite, etc.) can serve as excellent solvents for other metallic sulfides that may exist in the ore deposit. Ferric sulfate oxidizes sulfide minerals to soluble sulfates, and in turn is reduced to ferrous sulfate. At the expense of hydrogen ions and oxygen, ferrous sulfate is oxidized (probably quickly) back to ferric sulfate according to the reaction:

$$2Fe^{+2}+2H^{+}+1/2\ O_2 \longrightarrow 2Fe^{+3}+H_2O$$

(Park and MacDiarmid, 1964, p. 481)

As can be noted in the equation, this process releases amounts of iron to the ground water system. Miller (1980, p. 327) reports that concentrations in excess of .3 ppm are commonly produced in this reaction. Iron at this level is not harmful to health, but is detrimental to taste, and can discolor the water.

The simple sulfides that do not contain iron are oxidized directly or are dissolved by ferric sulfate and sulfuric acid produced by the oxidation associated iron sulfides as in the following reaction:

$$Cu_2S\ \text{(chalcocite)}+2H^{+}+SO_4^{-2}+\frac{5}{2}\ O_2 \longrightarrow Cu^{+2}+2SO_4+H_2O$$

(Park and MacDiarmid, 1964, p. 419)

If the acidity of the ground water in the dump flow system is maintained, several associated minerals such as copper, silver, and zinc are leached. However, if neutralization of the acidic water occurs through contact with reactive waste rock, such as limestone or other carbonates, the metals will precipitate as stable minerals, and consequently transport of leached minerals will be halted or minimized (Park, 1964, p. 418).

Another inhibitor to leaching of metals from the mine dumps is the formation of gypsum resulting from the presence of zinc that occurs in the peripheral areas around the main ore deposit. In a limestone environment such as that found in the existing and proposed waste dumps in the study area, the zinc sulfate solution produced from oxidation of sphalerite (ZnS) reacts to form smithsonite and gypsum in the following manner:

$$Zn^{+2}+SO_4^{-2}+CaCo_3+2H_2O \longrightarrow CuSO_4\cdot 2H_2O\text{(gypsum)}+ZnCO_3$$

(Park and MacDiarmid, 1964, p. 420)

Formation of gypsum within the waste pile would serve to inhibit the flow of water through the dump, and hence decrease the overall movement of contaminants downward through the dump to the bedrock, and into the saturated flow system. Additionally, any decreased flow of oxygen into the system would inhibit the oxidation process given on page 15.

Beyond the basic chemical reactions of pyrites, oxygen, and water, it is suspected that acid formation may be influenced by complex biochemical reactions involving one or more types of bacteria (Miller 1980, p. 327). This process is reported to occur in a comprehensive study by Galbraith, Williams and Siems (1972). Their study was in a mining area near Coeur d'Alene, Idaho, and analyzed the leaching of metals from old mine dumps

and the possible mechanism of sulfide-oxidizing and sulfur-oxidizing bacteria. They concluded that the decrease in pH of water coming from the tailings was most likely due to action of bacteria (Gailbraith, et al., p. 49). This kind of action may not be occurring at Kennnecott, since the pH of the water is higher than that observed at Coeur d'Alene. (Most samples taken recently in the Bingham area are in the range 7.0 to 7.5 whereas the Coeur d'Alene study showed pH's of 6.5 to 7.0.)

If oxygen is prevented from entering the system, and anerobic conditions prevail, then the bacteria could convert dissolved sulfate to sulfide and dissolved nitrate to ammonia or nitrogen gas. Reaction of the sulfide with certain metals will produce highly insoluble precipitates, such as the sulfides of arsenic, cadmium, copper, iron, lead, mercury, molybdenum, nickel, silver and zinc (Runnels, 1970, p. 378). This process, then, could be beneficial to the overall quality of the ground water system through precipitation of metals which prevents their entering the ground water system.

Processes such as these could also operate in the undisturbed bedrock, since the same minerals are present. Any natural leaching occurring in the bedrock would likely be extremely minimal because of the much reduced surface area relative to that found in overburden dumps. Although the mineralized beds are highly fractured as discussed in the geology section, the fracturing would not likely provide adequate surface area and required oxygen to support natural leaching of heavy metals to the extent of that demonstrated in the previously described chemical reactions.

Sulfate concentrations are derived from the oxidation of pyrite as described above. Sulfates can also be caused by leaching from the soil cover. Studies by Hem (1970, p. 165) indicate that soils in semiarid and arid regions are not fully leached, and as a result, surface and underground waters can become relatively enriched in dissolved solids. Sulfates could be "flushed out" of the soil during intense rainfall events. Sulfate is a predominant anion in many situations such as this.

A good indicator of ground water quality is the water flowing from the Butterfield Portal (S-53, plate 1). This site should provide an excellent measure of water quality resulting from the mine and dumping activity, since the portal extends underneath several dumps, and is of substantial length. Values for TDS are above the USPHS 1962 standard, but are below the Utah MCL. For SO_4, the values were high (500 to 800 mg/l) in the early years of record, but have dropped to values (about 400 mg/l) below the Utah MCL; however SO_4 is still above the 1962 USPHS recommended standard. These data should be representative of the level of chemical constituents resulting from natural leaching.

Effects of Contaminants

In addition to examining what the levels of chemical constituents are in the various wells, springs and streams, it is important to view what the presence of these constituents means in terms of health and safety of the water users in the area.

The effects of various contaminants on uses of water supplies have been described in detail by McKee and Wolf (1963) who established the definitive work on water quality criteria through an exhaustive search of existing literature and through personnel contact. Since then, notable studies have been conducted by the National Technical Advisory Committee to the Secretary of the Interior (1968), the National Academy of Sciences (NAS) (1972), and Hem (1970).

The following discussions are important as they relate to particular potential water pollutants and their effects on the use of water for drinking supplies.

Arsenic

Arsenic occurs mostly as the arenides of true metals or pyrites. It is usually recovered as a by-product from the processing of other ores, e.g., copper, lead, zinc and tin. Elemental arsenic is insoluble in water but many of the arsenates are highly soluble (McKee and Wolf, 1963, p. 140). Aresenic is also found in some pesticides and herbicides as sodium arsenate (Fetter, 1980, p. 352). Some arsenic can thus enter ground water supplies in agricultural areas.

The aresenic content in drinking water in most United States supplies ranges from a trace to approximately 0.1 mg/l. No adverse effects have been reported from the ingestion of these waters (NAS, p. 56). Concentrations of up to 1.0 mg/l have been reported to be present in drinking water, and used for short periods of time, has produced no ill effects (McKee and Wolf, 1963, p. 140).

Aresenic is notorious for its toxicity to humans. Ingestion of as little as 100 mg ususally results in severe poisoning, and 130 mg has been reported as being fatal (McKee and Wolf, 1963, p. 140). Arsenic accumulates in the body so that small doses become fatal in time (McKee and Wolf, 1963, p. 140).

In 1942 for the first time, the USPHS Drinking Water Standards prescribed a maximum permissible concentration of .05 mg/l and this mandatory limit is still in effect. In 1962, the USPHS recommended a limit of .01 mg/l with a mandatory limit of .05 mg/l upon which drinking water supplies should be rejected as a source (McKee and Wolf, 1963, p. 140). In 1972, the NAS (p. 56) gave the following recommendation pertaining to arsenic in drinking water:

> Because of adverse physiological effects on humans and because there is inadequate information on the effectiveness of the defined treatment process in removing arsenic, it is recommended that public water supply sources contain no more than 0.1 mg/l total arsenic.

Copper

Metallic copper is insoluble in water, but many copper salts are highly soluble as cupric or cuprous ions. Copper salts occur in natural surface waters only in trace amounts, up to about .05 mg/l. The chloride, nitrate, and sulfate of divalent copper are highly soluble in water, but the carbonate, hydroxide, oxide and sulfide are not. Cupric ions (Cu^{+3}) introduced into natural waters at pH7 or above will quickly precipitate as the hydroxide or as basic copper carbonate, $CuCO_3 \cdot Cu(OH)_2 \cdot H_2O$, or be removed by absorption and/or sedimentation. As a result, copper ions are not likely to be found in natural surface waters or ground water. (McKee and Wolf, 1963, p. 169).

Because copper in concentrations high enough to be dangerous to human beings renders the water disagreeable to taste, it is believed that copper is probably not a hazard in domestic water supplies. Unlike arsenic, copper is not retained in the body system and there has been no evidence that poisoning has ever occurred as a result of copper in water (McKee and Wolf, 1963, p. 169).

Threshhold concentrations for taste have been generally reported in the range 1.0 to 2.0 mg/l, while as much as 5.0 to 7.5 mg/l makes the water completely undrinkable (McKee and Wolf, 1963, p. 169).

The limit for copper has varied relatively widely over the years. In 1925, the USPHS standards established a limit of 0.2 mg/l which was a mandatory limit. In 1942, the limit was raised to 3.0 mg/l, and was made a recommended limit, but not mandatory. In 1962, the USPHS standards gave a recommended limit of 1. mg/l. This limit was based on taste considerations (U.S. HEW, 1962, p. 39). The NAS 1972 recommendation is:

> To prevent taste problems and because there is little information on the effect of the defined treatment process on the removal of copper, it is recommended that copper in public water supply sources not exceed 1 mg/l.

Iron

Iron is objectionable in drinking water mainly because of taste considerations. Iron occurs frequently in ground waters in the reduced (Fe^{++}) state, since exposure to oxygen results in oxidation, resulting in hydrated ferric oxide, which is much less soluble (NAS, 1972, p. 69).

The taste threshold for iron depends on the form of iron present. Cohen et al. (1960) using a statistically controlled taste panel found that the median taste threshold for ferrous sulfate in spring water occured at 1.8 mg/l of iron, but for the most sensitive tasters, it was .12 mg/l. For ferrous sulfate in distilled water, the threshold concentration was 3.4 mg/l; but for the more sensitive individuals, it was .04 mg/l. Five percent of the observers in the testing procedure were not able to detect ferrous iron at a concentration of 256 mg/l in distilled water.

The NAS recommendation is:

> On the basis of user preference and because the defined treatment process can remove oxidized iron but may not remove soluble iron (Fe^{++}), it is recommended that .3 mg/l soluble iron not be exceeded in public water supplies.

Magnesium

Magnesium is an essential mineral element for human beings, the daily requirement being about .7 grams. Magnesium is considred relatively nontoxic to man and not a public health hazard because before toxic concentrations of the element are reached in water, the taste becomes very unacceptable. At high concentrations, magnesium salts have a laxative effect, expecially upon new users. A tolerance can be developed over a period of time (McKee and Wolf, 1963, p. 261).

The taste threshold for magnesium ($MgSO_4$) has been reported (McKee and Wolf, 1963, p. 211) as low as 100 mg/l, with most individuals reporting taste at 500 mg/l.

The 1946 USPHS drinking water standards recommended a limit of 125 mg/l but there is no limit in the 1962 standards. The 1958 World Health Organization (United Nations) International Standards have a "permissible limit" of 50 mg/l and an "excessive limit" of 150 mg/l, but no maximum allowable concentration. The 1961 WHO European standards have a recommended limit of 125 mg/l, but if the sulfate exceeds 250 mg/l, magnesium is limited to 30 mg/l.

The recent study by the NAS (1972) did not address magnesium in their analysis of drinking water quality criteria.

Manganese

Manganese is objectionable in drinking water supplies because of taste.

Manganese occurs in the reduced state (Mn^{++}) frequently in ground waters since exposure to oxygen results in oxidation to the much less soluble hydrated manganese oxides (NAS, 1972, p. 71). In this reduced state,

manganese can be leached from soils or rock in high concentrations (McKee and Wolf, 1962, p. 214). Manganese frequently occurs with iron in ground water.

The 1962 USPHS standards set a recommended limit of .05 mg/l. The 1958 WHO International Standards prescribe a "permissible limit" of .1 mg/l and an "excessive limit" of .5 mg/l, but there is no maximum limit given. The WHO European Standards have a recommended limit of .1 mg/l (McKee and Wolf, 1962, p. 214).

These limits have been established on the basis of esthetic and economic considerations rather than physiological hazards. In concentrations not producing unpleasant taste, manganese is regarded by most investigators to be of no toxicological significance in drinking water. However, some cases of manganese poisoning have been reported in the literature. (Small outbreaks occured in Japan resulting from dry-cell batteries buried nearby a well.)

According to literature reviews by McKee and Wolf (1962, p. 214) the taste threshold for manganese in spring water occurred at about 180 mg/l for the median of a large panel, but at about 3.5 mg/l for the most sensitive members.

The NAS 1972 recommendation is:

> On the basis of user preference and because the defined treatment process can remove oxidized manganese but does little to remove soluble manganese (Mn^{++}), it is recommended that 0.05 mg/l soluble manganese not be exceeded in public water sources.

Sulfate

Sulfates occur naturally in waters, particularly in the western United States as a result of leachings from gypsum or other common minerals (McKee and Wolf, 1963, p. 275). Sulfates may also be produced as noted in an earlier section, by oxidation of iron pyrite (FeS).

In drinking water, the USPHS (1962) recommended a limit of 250 mg/l. This limit does not appear to be based on taste or physiological effects other than a laxative action to new users. Waters that exceed this limit are commonly and constantly used without adverse effects (McKee and Wolf, 1963, p. 276). The only adverse effect reported in the literature is that of the laxative effect. This effect varies for different users, depending on their past exposure to varying doses of high sulfate drinking water. The NAS 1972 recommendation is:

On the basis of taste and laxative effects and because the defined treatment process does not remove sulfates, it is recommended that sulfate in public water supply sources not exceed 250 mg/l where sources with lower sulfate concentrations are or can be made available.

Total Dissolved Solids

Total dissolved solids (TDS) are objectionable because of possible physiological effects, mineral taste, and economic consequences (NAS, 1972, p. 90). Dissolved solids consist primarily of carbonates, bicarbonates, chlorides, sulfates, phosphates, nitrates of calcium, magnesium, sodium and potassium, with traces of iron, manganese and other substances. (McKee and Wolf, 1963, p. 182).

The 1962 USPHS standards recommended that water containing TDS in excess of 500 mg/l not be used if less mineralized water supplies were available. This is influenced primarily by considerations of taste.

McKee and Wolf (1963) document several communities in the U.S. that utilize drinking water containing more than 500 mg/l TDS without having obvious ill effects.

An example of the range of values for TDS limits is seen in the World Health Organization (United Nations) 1958 standards which set a "permissible limit" of 500 mg/l and an "excessive limit" of 1500 mg/l, but no "maximum limit" (McKee and Wolf, 1963, p. 182).

Impacts to Ground Water System

Total Dissolved Solids and Sulfate

In order to assess the potential impacts of natural leaching of the mine dumps on ground water quality of the area, it would be most meaningful to examine the present and historical ground water quality in the valley fill near the mouth of Butterfield Canyon, since this is the area of projected ground water movement coming from the mine dumps.

Several wells exist in the vicinity of Lark and Herriman that provide a good indication of possible water contamination from the mine area. In addition, a few wells near the Nevada tract should provide indications of the chemical quality of the water coming from the existing dumps since water would be moving toward Butterfield Creek, and poor water quality should show up at these places.

Well K-71 is located next to the Nevada tract on the east boundary (see plate 1). Water quality data provided by Kennecott for the years 1969 to 1979 are plotted on Figure 1 for TDS and Figure 2 for SO_4 (Table 12e). The values for TDS generally range from about 580 ppm to 980 ppm; however, several spikes occur that show values of 1000 to 1380 ppm. These high values are isolated occurrences and do not represent the general condition of the ground water. Eliminating these isolated occurrences produces a trend that has been relatively flat since the start of data gathering. The values of 580 to 980 ppm for TDS are below the less stringent Utah primary standard for drinking water (2000 mg/l).

At well K-71, SO_4 shows a general range of from about 100 ppm to 200 ppm. These figures indicate that the well water is likely receiving some water from the mine dump area because of the higher than background sulfates. Relative to the drinking water standards, these values are below both the USPHS recommendation and well below the Utah standard of 500 mg/l (Table 12d).

Station S-53 is located at the Butterfield Tunnel. Analyses of this water should provide some insight into water moving through the bedrock since the tunnel extends into the mountain for 3-1/2 to 4 miles, although away from the dumps nearest the Nevada tract. Note that the values of TDS (Table 12e, 12f, 12g, and Fig. 3) at this station has been steadily decreasing since the inception of data collection in 1969. Although the long-term trend has been downward, the values of TDS making up the trend exceed the 1962 PHS recommended drinking water standard, but do not exceed the state of Utah primary standard. SO_4 at the Butterfield Tunnel (Tables 12f, 12g, and Fig. 4) showed high initial values during the early months of collecting data, but are continuing in a slight downward trend. These SO_4 values are over the recommended USPHS limit of 250 ppm, and samples taken since 1974 have been slightly below the Utah standard of 500 mg/l.

Station K-69 is a well near one extension of the Yosemite dump. This site is the nearest sampling location to any of the dumps, and should be a good location to detect any contaminant transport moving away from the dump. Table 12a, 12b and Figures 5 and 6 show TDS and SO_4 values for this site. It is interesting to note that the values of SO_4 do not exceed the USPHS recommended limit except for a few of the early samples. For TDS at this site, the values are well below the Utah standard of 2000 mg/l, but are somewhat above the USPHS 1962 recommendation of 500 mg/l.

Site S-40 is a surface water site at Butterfield Creek spring. Table 12e shows TDS and SO_4 values for this site. Note that both parameters consistently are well below the USPHS 1962 recommended standard, and the Utah standard.

Site S-22A is a surface site at Willow Springs, downslope from the Saints Rest dump (see map, plate 1). Although data only exists since mid-1980, it shows that the values exceed the 1962 USPHS recommended standard. Most recent data for SO_4 shows a downward trend; however, a similar trend occurred in early 1981, then went up again in a cyclic pattern evident

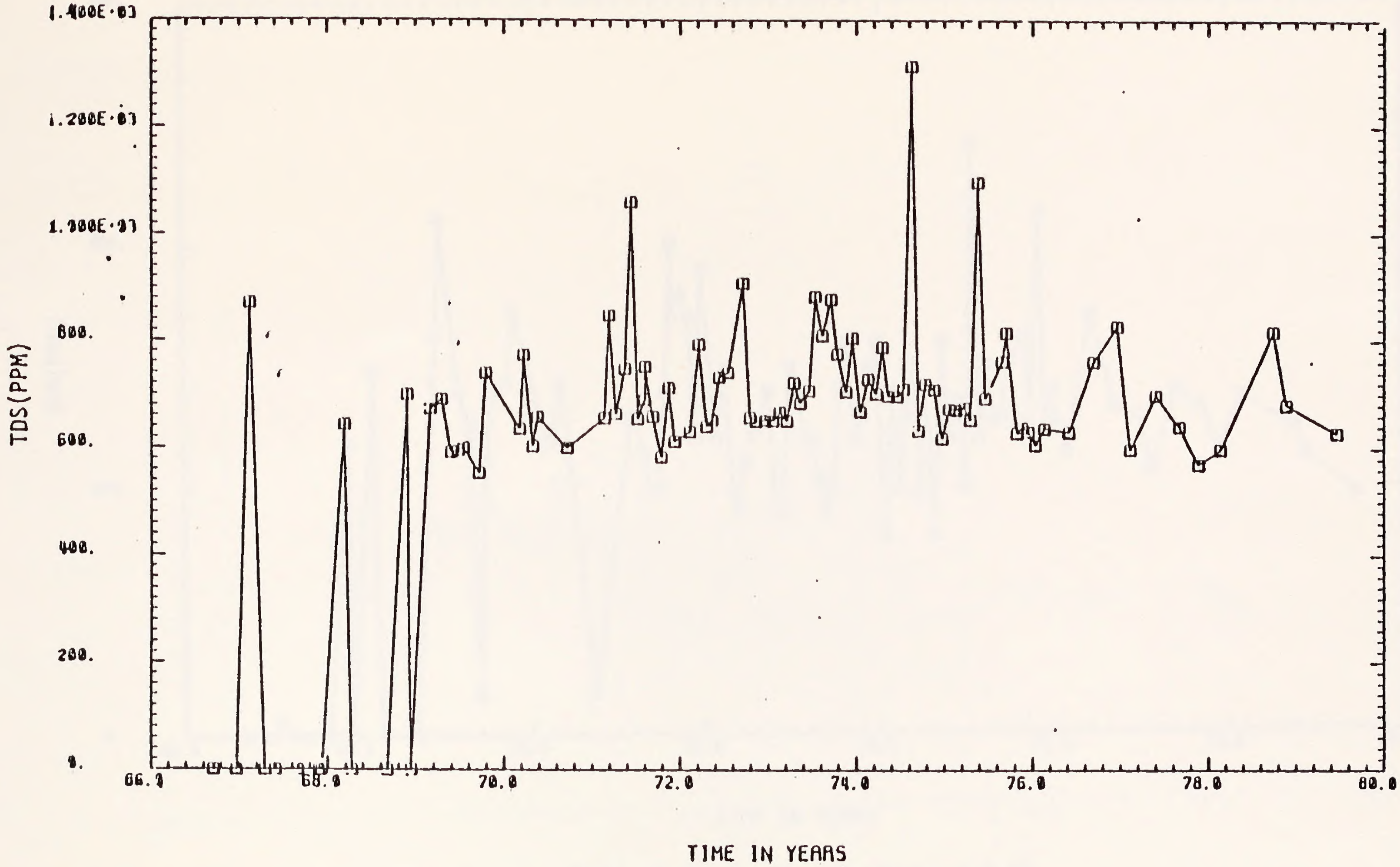

Fig. 1 Plot of TDS at Sample Station K-71

(after Doesburg and Nelson 1981, Kennecott Corp. data)

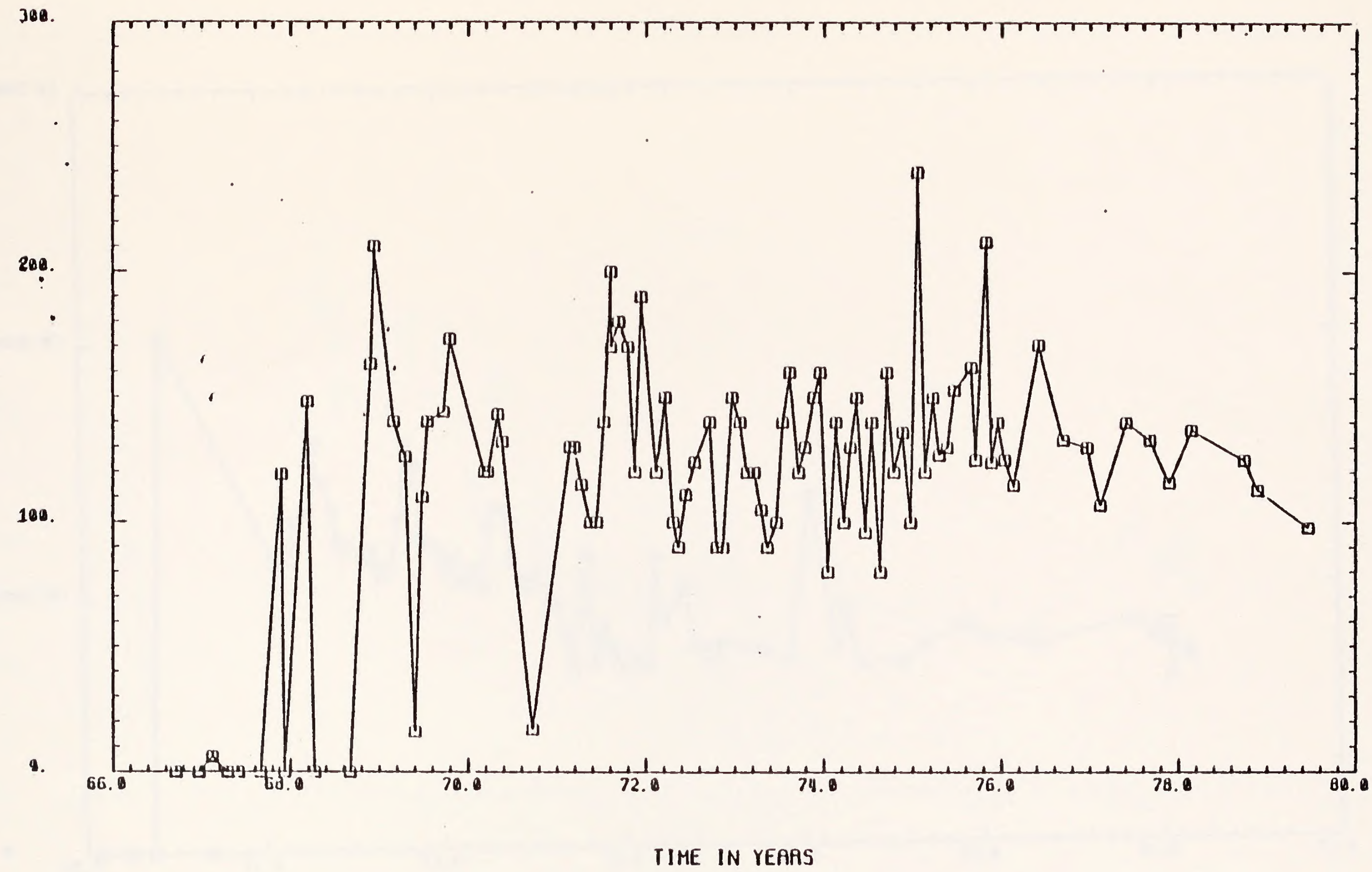

Fig. 2 Plot of SO_4 at Sample Station K-71

(after Doesburg and Nelson, 1981, Kennecott Corp data)

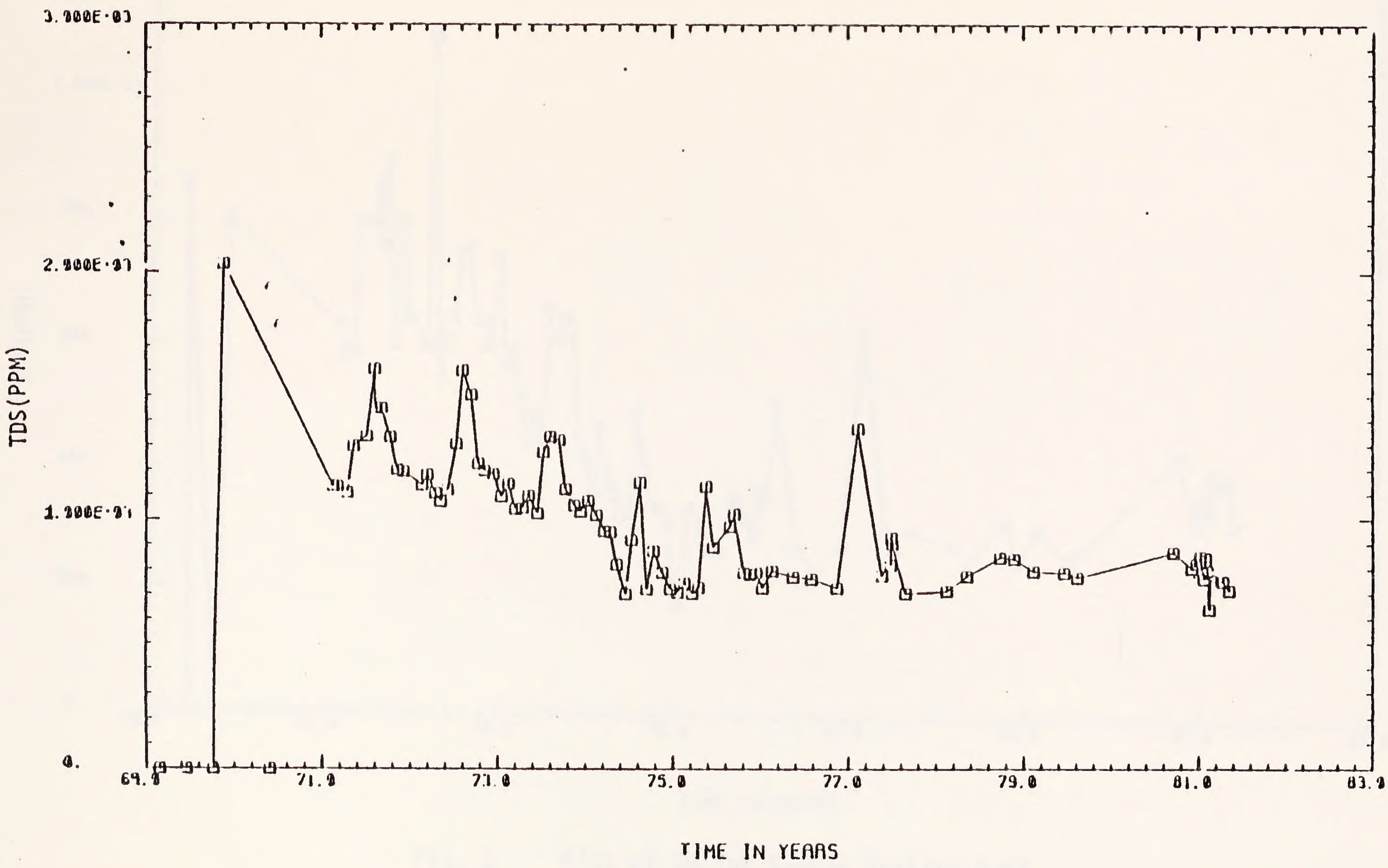

Fig. 3 Plot of TDS at Sample Station S-53

(after Doesburg and Nelson, 1981. Kennecott Corp data)

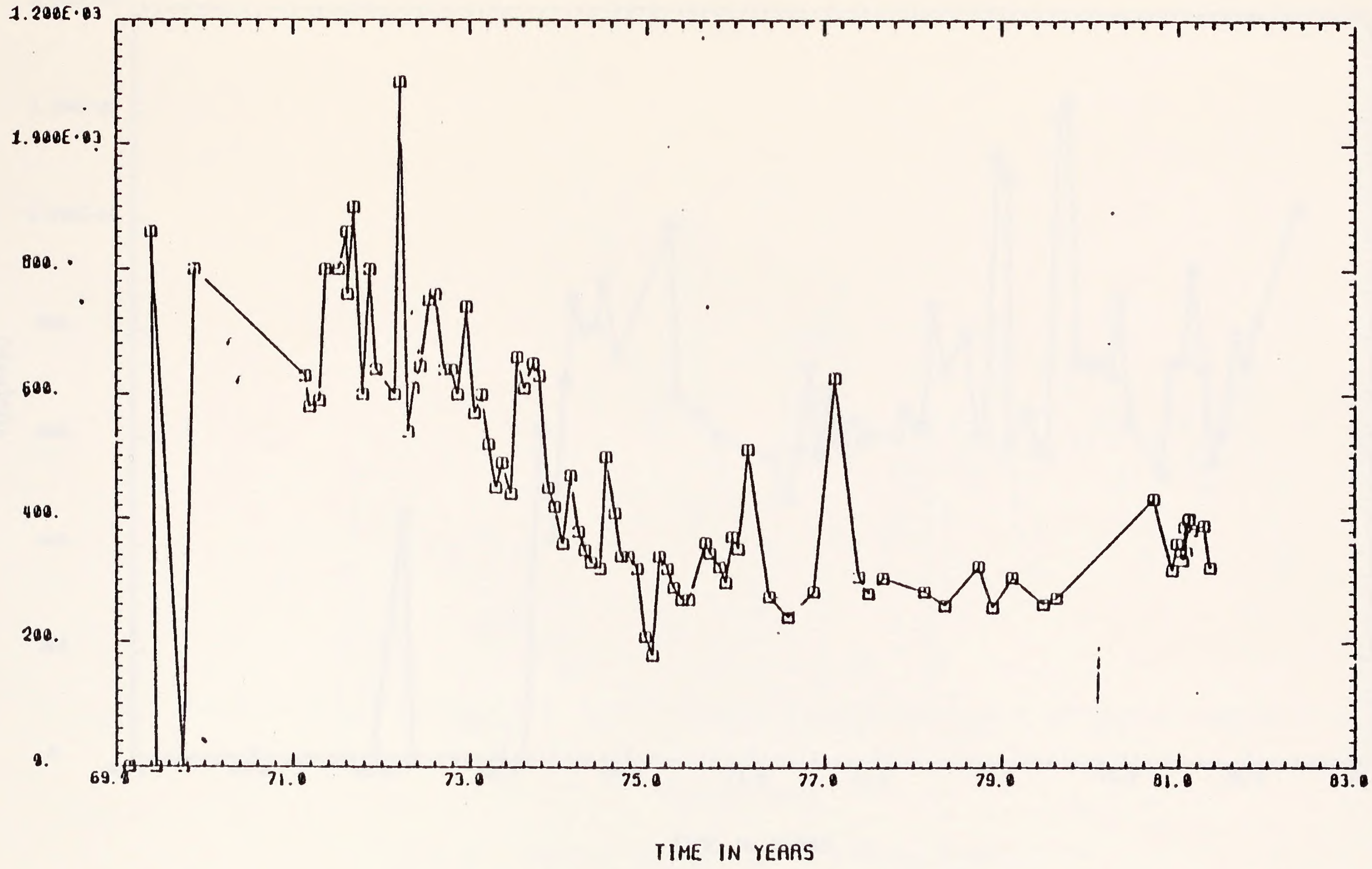

Fig. 4 Plot of SO_4 at Sample Station S-53

(after Doesburg and Nelson 1981, Kennecott Corp. data)

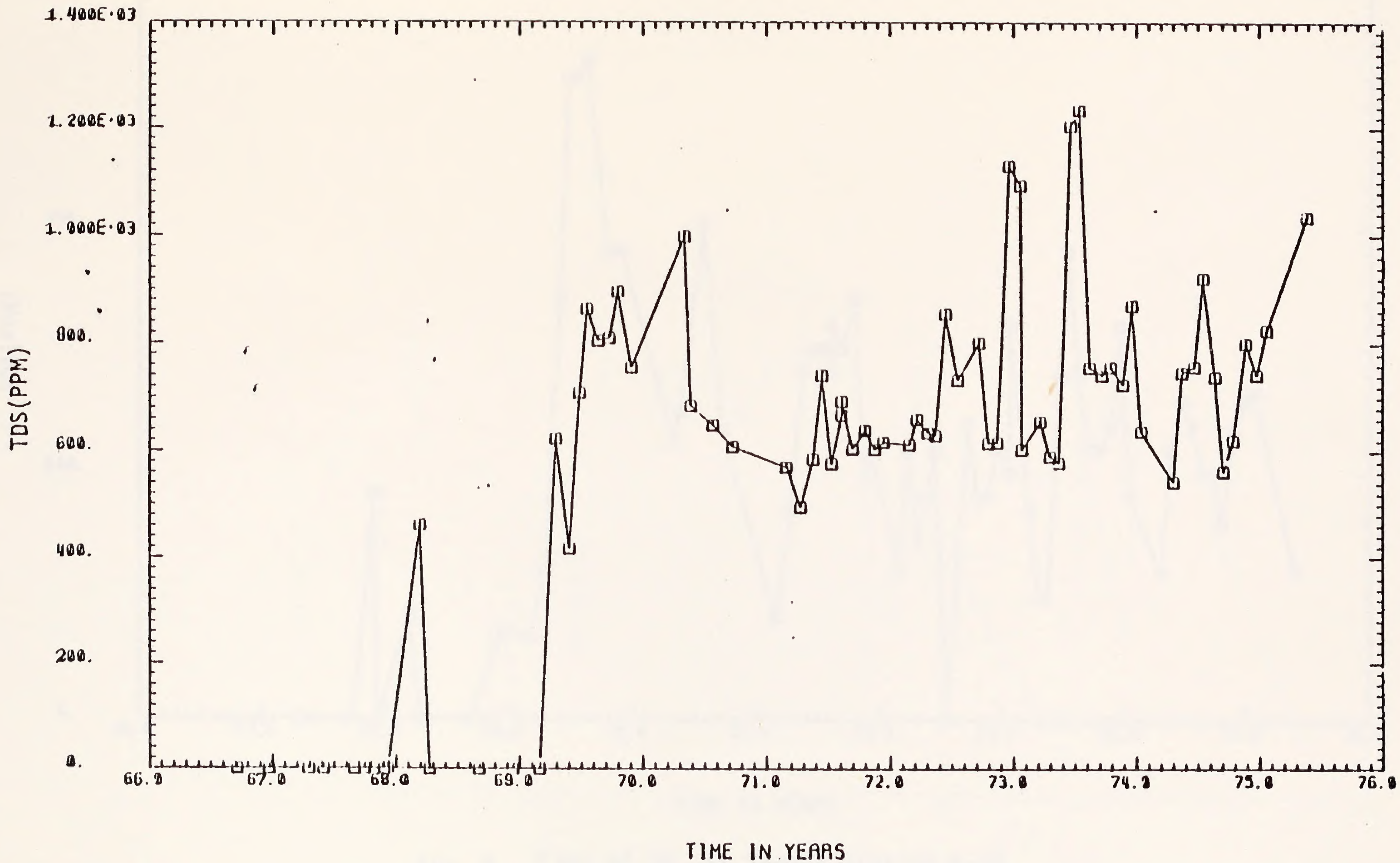

Fig. 5 Plot of TDS at Sample Station K-69

(after Doesburg and Nelson 1981 , Kennecott Corp data)

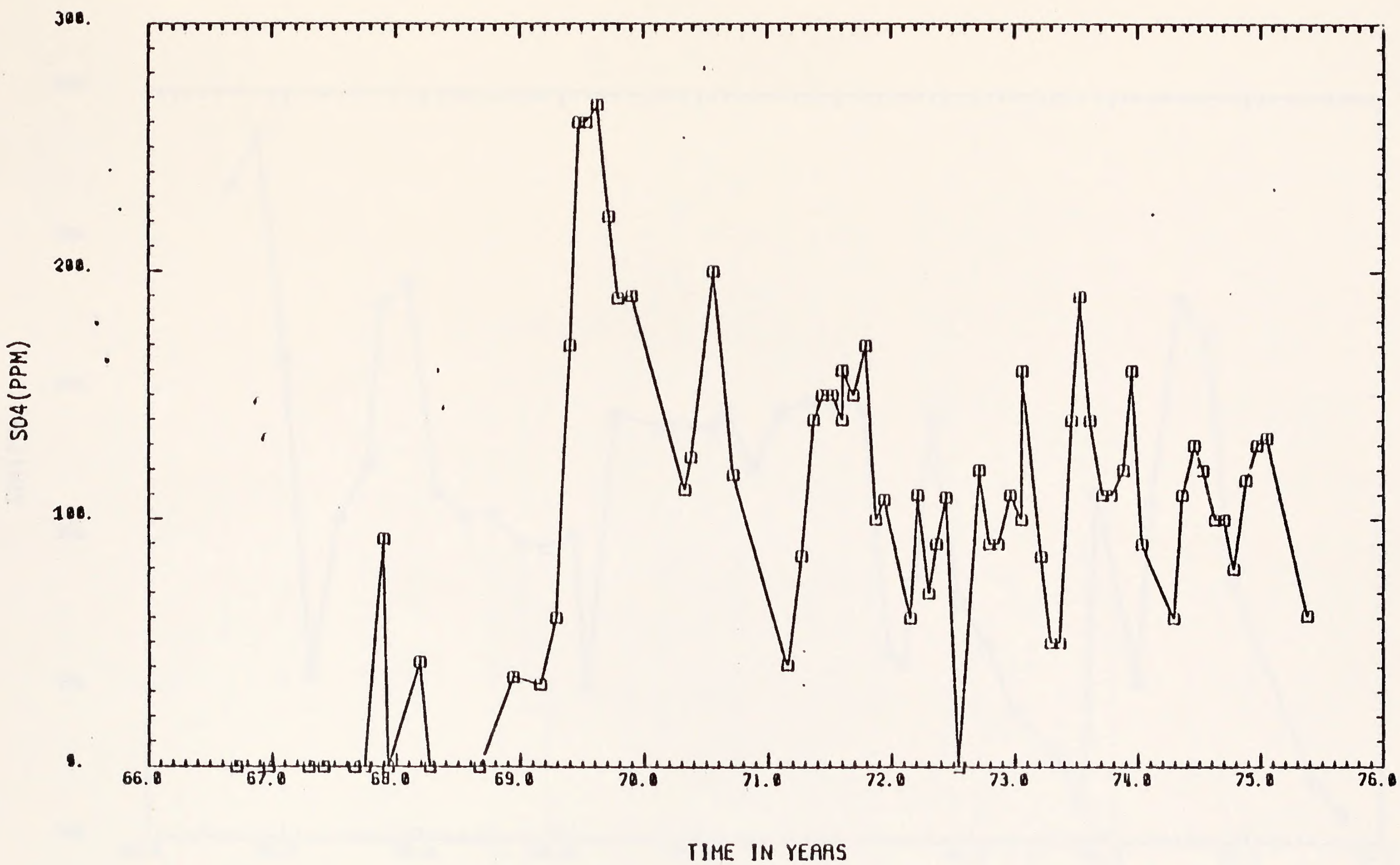

fig. 6 Plot of SO_4 at Sample Station K-69

(after Doesburg and Nelson 1981, Kennecott Corp data)

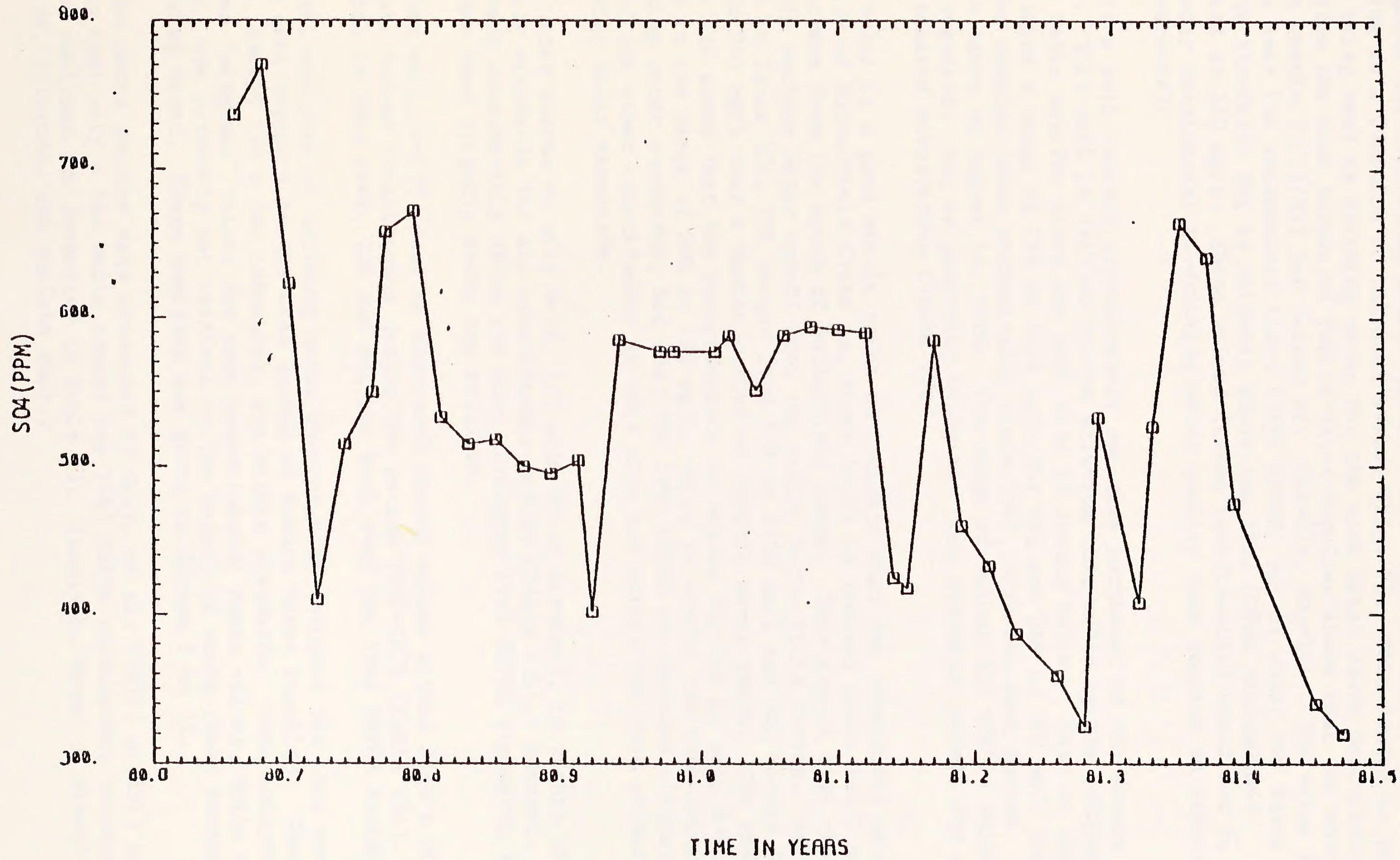

Fig. 7 Plot of SO_4 at Sample Station S-22A

(after Doesburg and Nelson 1981, Kennecott Corp data)

throughout the monitoring period (Table 12a). This is likely due to leaching as a function of rainfall events (Fig. 7). This source is presently being used as drinking water for the Lark Water Users Association. Data from the Utah Bureau of Public Water Supplies shows that the most recent sample (4/13/81) had values of: TDS=876, SO_4=281. The value for TDS is over the recommended limit (1962 USPHS) but is under the State Primary Standard; SO_4 is slightly above the 1962 USPHS recommended standard of 250 mg/l. These values (taken individually) would not be seriously detrimental to drinking water quality (see section on effects of contaminants).

W-41 is a well located approximately one mile northeast of the Nevada tract. This well is drilled in the alluvium that makes up the extensive water table aquifer along the west side of Jordan Valley. Data at this site shows a range of 796 to 1336 mg/l for TDS and 244 to 580 mg/l for SO_4 for samples taken periodically since 1967, with the most recent sample taken on August 14, 1980. The range of values for TDS is below the Utah standard. SO_4 is generally below the Utah standard, except for a few isolated occurrences (Table 12c).

Site S-21A is a good sample point to indicate what the integrated water quality of Butterfield Creek is, since S-21A is located about 1-1/2 miles downstream from the mouth of Butterfield Creek. This sample site should contain surface water runoff from the entire Butterfield Canyon. As can be noted in Table 12d, TDS ranges from 538 to 2450 mg/l and SO_4 ranges from 141 to 943 mg/l over a sample period of roughly seven years. The data in Table 12d shows that the preponderance of values for TDS at site S-21A falls in the range of 600 to 750 mg/l, which is within the Utah primary drinking water standards, but over the 1962 USPHS recommended standard. All of the other constituents at this site are within the Utah primary drinking water standards.

Well water tested at site W-18, 1/2 mile NW of Herriman, is within the Utah primary standards for all constituents tested (Table 12a). However, TDS has been considerably above the more stringent 1962 USPHS standard, and SO_4 has been slightly above the standard.

Another well, W-130 (west of Herriman) showed values within Utah's MCL's for all tested constituents during the period 1967-1978 (Table 12c). As is typical in this area, TDS and SO_4 are both over the 1962 USPHS standard.

Several analyses of drinking water sources were reviewed for this study, from data supplied by the Utah Bureau of Public Water Supplies. These data, except for a few instances, are within standards. Some analyses showed "marginal" values for some constituents; these values, while marginal, are currently not critical to the safety of using these sources for drinking water. These analyses are given in Tables 3 to 11.

Ground water quality data presented by Hely, et al. (1971, p. 197) indicates that only a few wells exceed the 1962 USPHS recommended standards. These analyses are presented in Table 13. (Analysis based on dissolved solids, chloride, and sulfate only.)

water quality data supplied by kennecott copper corp.

Well #	Location	Date	Depth	Cond.	Temperature (C°)	Milligrams/Liter														
						PH	CU	TDS	SO_4	Cl	Mg	Al	Hardness	Fe	Na	K	Ca	HCO_3	CO_3	NO_3
(C-3-2)																				
W-18	26 ccc	05/20/69				7.2	0.020						1,044							
		08/21/69				7.5	0.130						804							
		07/07/71				7.6	0.010	1,314	370				756							
		07/07/71				7.5	0.010	1,403	390				684	0.16						
		07/18/74				7.6	0.010	1,628	240				752							
		08/15/75		1,260		6.5	0.010	1,528	392					0.01						
		06/29/76		1,540		7.3	0.020	1,268	312	166				0.02						
		06/19/78		1,450	9.0	7.3	0.080	1,558	402	175	68.	-0.1								
		07/11/79		1,160	12.3	7.5	0.020	1,448	321	250	68.	-0.1								
S-22	31 ccd	07/28/80		1,400	18.0	6.8	0.070	1,380	736	112		0.1		0.18						
		08/05/80		1,460	17.0	7.0	0.040	1,488	770	110		-0.1		0.06						
		08/12/80		1,500	19.0	6.8	0.050	1,398	623	121		0.3		0.08						
		08/18/80		1,250	17.0	6.4	-0.010	1,350	410	116	- 0.	-0.1		0.04						
		08/26/80		1,450	18.0	6.2	0.010	1,378	515	114	70.	-0.1		0.10						
		09/03/80		1,400	17.0	7.5	0.130	1,300	550	116	68.	0.1		0.33						
		09/08/80		1,450	16.0	7.1	-0.010	1,314	658	118	68.	-0.1		0.26						
		09/16/80		1,350	14.0	7.8	0.070	1,356	672	122	65.	0.1		0.03						
		09/22/80		1,400	14.0	6.6	0.020	1,372	533	118	61.	0.1		0.03						
		09/29/80		1,480	16.0	7.2	-0.010	1,394	515	116	72.	0.1		0.05						
		10/07/80		1,500	18.0	7.1	0.020	1,388	518	134	65.			0.02						
		10/13/80		1,150	15.0	7.1	-0.010	1,442	500	104	57.	-0.1		0.03						
		10/20/80		1,500	16.0	6.9	-0.010	1,984	495	94	76.	0.1		0.02						
		10/28/80		1,600	13.0	7.0	0.010	1,288	504	124	73.	-0.1		0.04						
		11/03/80		1,450	17.0	7.0	-0.010	1,228	402	130	75.	-0.1		0.05						
		11/10/80		1,380	14.0	6.9	-0.010	1,298	585	146	75.	-0.1		0.04						
		11/18/80		1,350	14.0	7.0	-0.010	1,300	577	100	74.	-0.1		0.05						
		11/24/80		1,350	13.5	6.9	-0.010	1,254	577	96	70.	-0.1		-0.01						
		12/04/80		1,200	11.5	6.9	0.010	1,384	577	104	68.	0.1		-0.01						
		12/09/80		1,300	13.0	6.8	-0.010	1,430	588	142	73.	-0.1		0.05						
		12/15/80		1,300	12.0	6.8	0.010	1,252	551	162	78.	0.1		0.02						
		12/23/80		1,300	12.0	6.7	0.010	1,272	588	128	75.	-0.1		0.05						
		12/29/80		1,280	13.5	6.8	0.020	1,268	594	128	0.	0.1		0.06						
		01/06/81		1,300	12.0	6.9	-0.010	1,288	592	140	71.	0.1		0.06						
		01/12/81		1,300	12.0	7.0	0.010	1,254	590	120	69.	0.3		0.01						
		01/20/81		1,300	13.0	7.2	0.030	1,276	425	140	68.	-0.1		0.01						
K-69	31 ccc	08/16/66	75.00			7.2	0.003						376							
		11/18/66	46.00			7.3	0.055						462							
		03/16/67	47.00			7.6	0.040						599							
		04/28/67	41.00			8.1	0.010						410							
		07/27/67	33.00			7.4	0.075						359							
		08/25/67	43.00			7.9	0.068						427							
		10/23/67	45.00			7.2	0.073		92				547							
		11/06/67	46.00			7.5	0.040						273							
		02/07/68				8.0	0.028	461	42	97	32.		479	0.11	62	3	42	281	1	2.00
		03/06/68	47.00			6.6	0.118						393							
		07/30/68	35.00			7.9	0.060						308							
		11/08/68	21.00			8.3	0.110		36				256							
		01/27/69				7.0	0.250	623	33				342							
		04/23/69	17.00			7.6	0.001	709	170				633							
		05/23/69				7.3	0.010	864	260				633							
		06/13/69	27.00			7.5	0.450	805	260				701							
		07/17/69				7.4	0.210	810	267				753							
		08/21/69				7.4	0.150	896	222				616							
		09/16/69				7.5	0.010		189				582							
		10/24/69				7.7	0.010	756	190											
		03/31/70				7.6	0.030	999	112				496							
		04/16/70				7.2	0.010	685	125				479							
		06/23/70				7.7	0.010	649	200				514							
		08/18/70	46.00			7.5	0.010	609	118				753							
		01/26/71				7.1	0.010	571	41				314							
		01/27/71				7.1	0.010	571	41				314							
		03/09/71	39.00			7.7	0.150	496	85				328							
		04/12/71	20.40			7.3	0.010	586	140				342							

Table 12a

water quality data supplied by kennecott copper corp.

Well #	Location	Date	Depth	Cond.	Temperature (C°)	PH	CU	TDS	SO_4	CL	Mg	Al	Hardness	Fe	Na	K	Ca	HCO_3	CO_3	NO_3
						Milligrams/Liter														
K-69	31 ccc	05/10/71				7.3	0.130	742	150				428							
		06/08/71	28.40			8.1	0.010	578	150				299							
		07/06/71	34.10			7.7	0.050	668	140				356							
		07/06/71	34.10			7.2	0.010	694	160				257							
		08/10/71				7.4	0.020	606	150				399							
		09/15/71	42.30			6.9	0.010	640	170				485							
		10/12/71	45.00			7.5	0.010	605	100				456							
		11/10/71	44.35			7.5	0.180	618	108				342							
		01/24/72	44.00			6.8	0.040	614	60				356							
		02/14/72	41.62			7.1	0.360	661	110				371							
		03/17/72	28.00			7.3	0.010	636	70				385							
		04/11/72	31.10			7.3	0.030	631	90				285							
		05/09/72	23.16			7.8	0.050	856	109											
		06/13/72	28.30			7.2	0.050	734												
		08/16/72	35.95			7.3	0.610	803	120				564							
		09/13/72	36.98			6.6	0.180	617	90				462							
		10/11/72	41.75			7.2	0.050	618	90				410							
		11/14/72	37.10			7.2	0.050	1,130	110				582							
		12/19/72	40.02			7.6	0.140	1,094	100				445							
		01/23/73	41.87			7.5	0.060	605	160				369							
		02/15/73				7.6	0.030	657	85				646							
		03/16/73	35.87			7.5	0.020	592	50				342							
		04/11/73	26.79			7.6	0.060	580	50				192							
		05/17/73	19.47			7.1	0.370	1,205	140				383							
		06/12/73	42.60			7.0	0.360	1,235	190				862							
		07/11/73	29.94			7.4	0.060	757	140				410							
		08/14/73	32.54			7.7	0.080	743	110				355							
		09/11/73	35.05			7.3	0.130	758	110				410							
		10/16-73	37.82			7.6	0.460	726	120				410							
		11/12/73	40.83			6.9	0.240	872	160				397							
		12/12/73	42.00			7.5	0.620	639	90				479							
		03/13/74	31.79			8.1	0.250	545	60				287							
		04/09/74	27.32			7.7	0.200	748	110				465							
		05/16/74	24.59			6.3	0.130	759	130				260							
		06/12/74	29.70			7.3	0.020	923	120				109							
		07/18/74	34.27			6.9	0.210	740	100				397							
		08/12/74	37.58			7.7	0.200	564	100				301							
		09/12/74	43/20			6.9	0.190	622	80				356							
		10/16/74	43.41			7.3	0.020	802	116				438							
		11/21/74	42.56			7.2	0.020	744	130				301							
		12/17/74	42.98		-	6.9	0.080	826	133				300							
		04/16/75	28.97	644		7.1	0.010	1,036	61											
W-41	32 dbc	04/15/61				7.5	0.035						599							
		06/15/62				7.0	0.053		224				564							
		04/15/63				7.2	0.001						633							
		10/24/63				6.8	0.020						633							
		10/01/64				6.9	0.017						718							
		04/15/65				7.1	0.350						650							
		10/15/65				7.7	0.022						616							
		04/15/66				7.4	0.050						701							
		10/28/66				7.1	0.046						804							
		09/28/67				7.4	0.054						650							
		10/31/67	15.00			6.9	0.028	1,183	460	58	39		855	0.05	40	3	62	310	1	7.00
		04/25/68				7.3	0.065						924							
		10/16/68				6.9	0.050						992							
		05/20/69				6.9	0.040						1,061							
		10/07/70				7.1	0.010						770							
		11/11/70				7.7	0.010	1,071	315											
		02/09/71				7.2	0.010	1,246	520				976							
		07/09/71				7.3	0.030	1,336	480				599	0.08						
		04/11/72				7.1	0.010	1,092	460				599							
		05/17/73				7.3	0.020	1,208	510				616							
		05/14/75		994		6.3	0.010	1,004	580					0.03						
		06/29/76		1,220		7.8	0.030	1,024	333	75										
		05/24/77		880		7.5	0.030	796	244	61										

Table 12b

water quality data supplied by kennecott copper corp.

Well #	Location	Date	Depth	Cond.	Temperature (C°)	PH	CU	TDS	SO_4	Cl	Mg	Al	Hardness	Fe	Na	K	Ca	HCO_3	CO_3
						Milligrams/Liter													
W-41	32 dbc	08/11/77		1.120	20.9	7.8	0.010	868	271	75									
		01/18/79		1.020	3.5	7.2	0.010	930	291	60	49	0.5							
		08/14/80		1,280	18.0	7.1	0.060	1,032	393	86	50	0.2							
S-21	33 cac	10/06/69								580									
		10/21/69				6.8	0.270	1,659	800										
		01/21/71				6.9	0.020	1,553	660										
		03/18/71				5.6			730										
		04/12/71				6.6	0.100	1,484	660										
		05/11/71				7.7	0.200	1,274	320										
		06/08/71				7.6	0.370	1,146	320										
		07/15/71				8.4	0.700	923	240										
		08/10/71					0.260	1,898	350										
		09/15/71				7.2	0.120	1,046	450										
		10/12/71				8.1	0.040	864	340										
		11/10/71				7.3	0.870	1,346	750										
		01/24/72				6.7	0.450	1,528	760										
		02/14/72				7.0	0.410	1,163	520					12.50					
		03/17/72				7.4	0.020	1,617	690										
		05/17/73				7.3	0.360	1,858	830										
		06/12/73				7.3	0.200	1,727	760										
		05/24/77		1,720		8.1	0.020	1,972	941	38									
		05/27/77		1,690		8.1	0.230	2,258	910	34				19.65					
		05/31/77		1,710		8.1	0.260	2,264	930	46				20.24					
		07/26/77		1,960	16.1	7.9	0.160	1,820	654					23.30					
		10/20/77		1,870	14.7	8.1	0.110	1,888	1,025	38	116	0.6							
		01/08/78		1,690	10.3	8.2	0.190	1,950	1,093	37	120	0.6							
		04/05/78		1,620	9.7	8.0	0.090	2,126	853	50	114	0.2							
		08/03/78		1,550	19.0	7.6	0.760	2,430	1,142	45	129	1.4							
		01/18/79		1,910	11.5	8.0	0.310	2,216	1,203	48	150	1.9							
		06/11/79		2,470	15.6	7.5	1.640	2,686	1,639	200	151	2.5							
		07/11/79		1,625	16.3	7.3	0.850	2,996	1,267	50	153	0.8							
		10/03/79		2,000	17.0	7.9	0.220	2,996	1,583	50	135	0.6							
		06/16/80		2,500	16.0	6.7	1,000	3,010	1,417	65	139	1.8		25.90					
		08/14/80		1,100	17.0	7.2	0.550	3,080	1,620	56	137	1.1		32.90					
		01/06/81		1,850	13.0	7.5	0.110	1,548	769	43	87	0.5		17.00					
S-21A	33 cab	09/11/74				7.2	0.070	780	270				328						
		10/17/74				7.4	0.030	810	240				383						
		11/21/74				7.5	0.010	718	170				410						
		12/18/74				7.7	0.030	762	150				301						
		01/17/75				7.8	0.090	694	260				410						
		02/19/75				7.5	0.070	678	230				301						
		03/13/75				7.7	0.040	766	270				438						
		04/16/75		565		7.6	0.020	1,086	220										
		05/14/75		804		7.5	0.020	740	260										
		07/23/75		806		7.2	0.040	736	229					0.04					
		08/13/75		763		7.7	0.010	850	221					0.04					
		09/23/75		818		7.5	0.070	678	291					0.79					
		10/16/75		573		7.2	0.040	706	224					0.38					
		11/12/75		566		7.2	0.060	726	261					0.33					
		12/09/75		570		7.2	0.490	720	225					4.79					
		01/16/76		570		7.5	0.040	702	213					1.46					
		04/15/76		576		8.0	0.010	580	215	39				0.09					
		06/29/76		780		8.0	0.050	566	141	37				1.04					
		10/14/76		760			0.020	614	187	37				0.22					
		01/10/77		450		8.4	0.180	690	192	40				4.30					
		04/18/77		570		8.7	0.050	832	179	25				0.46					
		05/24/77		630		8.4	0.060	780	161	56									
		07/26/77		840	21.0	8.3	0.100	600	195					2.10					
		10/20/77		700	10.2	8.8	0.020	642	213	38	35	0.5							
		01/08/78		560	4.2	8.6	0.030	620	205	35	40	0.5							
		04/05/78		490	9.6	8.5	0.090	618	173	40	31	0.2							
		08/03/78		680	15.0	8.0	0.030	694	211	37	35	0.7							
		01/18/79		840	4.2	8.5	0.030	730	210	80	35	0.6							
		06/11/79		1.270	13.1	7.9	0.570	1,254	560	50	71	1.4							
		07/11/79		560	15.6	8.2	0.030	538	150	43	42	0.3							

Table 12c

water quality data supplied by kennecott copper corp.

Well #	Location	Date	Depth	Cond.	Temperature (C°)	Milligrams/Liter														
						PH	CU	TDS	SO_4	Cl	Mg	Al	Hardness	Fe	Na	K	Ca	HCO_3	CO_3	NO_3
S-21A		10/03/79		2,500	17.0	8.1	0.230	2,450	223	50	119	0.3								
		06/16/80		70	17.0	7.9	0.030	604	178	37	36	0.5		1.00						
		08/14/80		1,770	18.0	7.2	0.350	2,114	943	52	91	0.9		19.40						
		01/06/81		610	5.0	8.3	-0.010	668	291	42	34	0.2		0.45						
W-130	33 dad	11/15/67				7.1	0.030	1,038	305	89	47		1,164	0.06	45	4		317	1	7.00
		03/09/71				7.7	0.400	1,146	380				756							
		07/09/71				7.4	0.010	1,250	380				627	0.07						
		07/10/74				7.5	0.010	1,362	340					0.05						
		08/15/75		1,140		6.3	0.010	1,370	407					0.09						
		08/11/77		1,270	16.3	7.6	0.010	1,116	373	130										
		09/27/78		1,080	13.5	7.1	0.030	1,184	390	115	54	-0.1								
W-131	36 bbc	10/15/67	190.00			7.3	0.028	1,082	118	310	35		1,061	0.04	55	5	156	329		
		02/09/71				7.4	0.010	1,338	160				770							
		07/07/71				6.9	0.010	653	160				336	0.07						
		06/19/72				6.8	0.010	1,612	150				685							
		11/19/73				7.2	0.040	1,410	190				711							
		06/12/74				8.0	0.010	1,539	290				383							
		08/15/75		1,660		6.5	0.010	1,616	310					0.13						
		06/29/76		1,890		7.4	0.040	1,320	333	215				0.04						
		01/18/79		1,980	4.4	7.7	0.010	1,632	588	225	4	0.3								
W-131A	36 bcb	06/19/72				7.0	0.120	1,601	129				822							
		11/19/73				7.3	0.040	1,456	250				739							
		06/12/74				7.6	0.010	1,536	310				547							
		08/15/75		1,370		6.5	0.010	1,990	298					0.09						
		06/29/76		1,780		7.5	0.020	1,262	265	215				0.01						
		08/11/77		2,130	21.6	7.6	0.010	1,356	404	230										
		01/18/79		1,760	11.3	7.7	0.010	1,368	404	235	1	-0.1								
(C-4-2)																				
K-71	6 acc	08/16/66	37.00			7.3	0.009						342							
		11/18/66	38.00			7.4	0.095						325							
		01/15/67				7.2		870	6	21					40	4	113	268	1	6.00
		03/16/67	37.00			7.7	0.035						479							
		04/28/67	36.00			7.8	0.019						530							
		07/27/67	35.00			7.3	0.020						479							
		10/23/67	36.00			7.5	0.011		119				564							
		11/06/67	37.00			7.2	0.040						445							
		02/07/68				7.7	0.032	643	148	97	35		701	0.06	38	4	52	238	1	1.00
		03/06/68	37.00			6.7	0.070						633							
		07/30/68	37.00			7.8	0.015						633							
		10/24/68				7.4	0.010	699	163											
		11/08/68	36.00			7.7	0.130		210				513							
		01/27/69				6.9	0.630	672	140				564							
		03/14/69				7.2	0.130	690	126				513							
		04/23/69	71.00			7.4	0.001	592	16				530							
		05/23/69				7.4	0.010	595	110				530							
		06/13/69				7.5	0.040	600	140				564							
		08/21/69				7.5	0.100	553	144				547							
		09/16/69				7.3	0.160	739	173				564							
		02/04/70				7.6	0.010	635	120				514							
		02/19/70				7.1	0.010	773	120				496							
		03/31/70				7.5	0.220	603	143				479							
		04/16/70				7.4	0.030	657	132				514							
		08/18/70	36.00			7.3	0.040	600	17				599							
		01/20/71				7.2	0.001	655	130				413							
		02/09/71	36.00			7.6	0.100	847	130				445							
		03/08/71	35.50			7.5	0.210	663	115				470							
		04/12/71	38.10			7.2	0.010	747	100				442							
		05/10/71				7.0	0.200	1,060	100				584							
		06/08/71	35.70			7.7	0.030	654	140				385							
		07/06/71				7.4	0.140	690	200				442							
		07/07/71	36.60			7.3	0.010	751	170				285							
		08/10/71				7.0	0.030	658	180				499							
		09/15/71	36.00			7.0	0.010	583	170				342							
		10/12/71	36.00			7.5	0.010	712	120				399							
		11/10/71	35.40			7.5	0.150	612	190				328							
		01/10/72	35.40			6.6	0.060	630	120				399							
		02/14/72	35.60			7.0	0.090	793	150				356							
		03/17/72	35.66			7.3	0.010	640	100				428							
		04/11/72	35.73			7.1	0.020	652	90				356							
		05/09/72	35.43			7.3	0.030	732	111											
		06/13/72	35.39			7.1	0.080	740	124				462							
		08/16/72	35.39			7.0	0.460	908	140				564							

Table 12d

water quality data supplied by kennecott copper corp.

Well #	Location	Date	Depth	Cond.	Temperature (C°)	PH	CU	TDS	SO_4	Cl	Mg	Al	Hardness	Fe	Na	K	Ca	HCO_3	CO_3	NO_3
						Milligrams/Liter														
K-71		09/13/72	35.67			6.8	0.310	657	90				325							
		10/11/72	35.82			7.3	0.020	650	90				462							
		11/15/72	35.44			7.2	0.040	652	150				479							
		12/18/72	35.65			7.8	0.210	651	140				410							
		01/17/73	35.21			7.2	0.030	667	120				411							
		02/14/73	35.18			7.9	0.020	651	120				383							
		03/13/73	35.00			7.5	0.040	722	105				396							
		04/11/73	35.23			7.3	0.040	684	90				208							
		05/17/73	35.39			7.2	0.100	707	100				383							
		06/12/73				7.2	0.050	883	140				383							
		07/11/73	35.64			7.4	0.030	810	160				396							
		08/14/73	35.54			7.8	0.040	878	120				383							
		09/11/73	35.58			7.2	0.050	776	130				383							
		10/16/73	35.42			6.8	0.040	706	150				424							
		11/12/73	35.44			7.0	0.050	806	160				383							
		12/13/73	35.22			7.6	0.010	669	80				397							
		01/17/74	35.50			7.6	0.010	729	140				383							
		02/20/74	35.42			7.5	0.020	702	100				301							
		03/13/74	35.72			7.8	0.050	789	130				369							
		04/11/74	35.72			7.7	0.100	698	150				395							
		05/16/74	35.80			6.9	0.030	697	96				246							
		06/12/74	35.61			7.6	0.030	711	140				301							
		07/18/74	39.43			7.0	0.100	1,314	80				506							
		08/12/74	35.65			7.8	0.060	634	160				328							
		09/12/74	35.73			6.9	0.070	720	120				383							
		10/16/74	35.68			7.4	0.070	710	136				383							
		11/21/74	35.00			7.1	0.020	620	100				301							
		12/17/74	35.00			7.0	0.060	674	240				301							
		01/17/75	35.00			6.8	0.060	672	120				356							
		02/20/75	35.00			6.2	0.140	676	150				328							
		03/13/75	35.00			6.8	0.020	654	127				274							
		04/16/75	35.00	692		7.0	0.010	1,098	130											
		05/14/75	35.04	712		6.5	0.050	694	153											
		07/23/75	35.00	728		6.3	0.040	762	162											
		08/13/75	35.00	714		6.6	0.070	816	125											
		09/37/76	35.00				0.070	630	212											
		10/16/75	35.56	712		6.6	0.060	640	124											
		11/12/75	35.56	824		6.6	0.070	632	140											
		12/10/75	35.00	625		6.2	0.070	608	125											
		01/16/76	35.00	655		6.4	0.040	638	115											
		04/28/76	34.90	681		6.8	0.030	632	171	94										
		08/09/76	34.94	683		6.6	0.060	762	133	92										
		11/16/76	35.09	667		7.4	0.020	828	130	92										
		01/10/77	35.00	700		7.6	0.130	600	107	90										
		04/25/77	35.15	700		8.2	0.240	700	140	100										
		08/02/77	35.51	860	11.8	7.9	0.250	642	133											
		10/20/77	35.84	690	10.2	7.6	0.060	572	116	85	31	0.7								
		01/19/78	35.61	590	9.5	8.0	0.280	600	137	90	46	4.3								
		08/28/78	35.80	840	12.0	6.9	0.120	818	125	110	35	0.7								
		10/19/78	35.67	770	11.5	7.7	0.060	682	113	90	35	0.3								
		05/17/79	35.36	710	12.1	7.8	0.020	630	98	87	33	0.2								
S-40	6 cdb	05/23/69				6.3	0.010	146					410							
		05/11/71				7.5	0.400	1,372	25				242							
		07/09/71				7.5	0.010	333	29				200	0.14						
		06/13/72				7.5	0.010	228	13				188							
		05/17/73				7.7	0.010	470	102				260							
		05/16/74				7.8	0.020	548	76				192							
		05/14/75		366		7.2	0.010	290	61					0.04						
		04/15/76		311		7.6	0.010	329	45	35				0.03						
		06/19/78		363	8.0	7.2	-0.010	318	30	22	19	-0.1								
		10/19/78		550	9.8	7.6	0.010	360	33	22	20	0.1								
		05/18/79		370	6.7	7.7	-0.010	302	23	25	15	-0.1								
		07/11/79		350	9.2	7.8	0.020	252	25	23	21	0.5								
		08/14/80		4,800	14.0	5.5	0.040	362	66	24	20	0.2		0.04						
		11/03/80		500	12.5	7.2	-0.010	374	43	24	19	-0.1		0.03						
(C-4-3)																				
S-53	12 aac	01/23/69				7.6	0.040						1,198							
		03/23/69				7.7	0.020						1,146							
		05/13/69				7.5	2.300						975							
		09/05/69				7.0	1.960						1,112							
		10/21/69				7.0	0.180	2,033	800											
		01/21/71				7.6	0.040	1,135	630											

Table 12e

water quality data supplied by kennecott copper corp.

Well #	Location	Date	Depth	Cond.	Temperature (C°)	Milligrams/Liter														
						PH	CU	TDS	SO_4	Cl	Mg	Al	Hardness	Fe	Na	K	Ca	HCO_3	CO_3	NO_3
S-53	12 aac	02/09/71				7.5	1.480	1,133	580											
		03/18/71				7.7	0.080	1,108	590											
		04/12/71				7.0	0.260	1,297	800											
		06/08/71				7.4	5.780	1,336	800											
		07/09/71				7.3	0.500	1,609	860				784							
		07/15/71				7.0	4.700	1,451	760											
		08/10/71				7.7	2.640	1,449	900											
		09/15/71				7.1	0.100	1,333	600											
		10/12/71				7.5	0.050	1,202	800											
		11/10/71				7.5	1.630	1,193	640											
		01/24/72				6.8	0.820	1,138	600											
		02/14/72				7.0	0.750	1,180	1,100											
		03/17/72				7.6	0.590	1,106	540											
		04/11/72				7.3	0.630	1,072	610											
		05/09/72				7.5	1.330	1,120	645											
		06/13/72					3.750	1,306	750											
		07/11/72				6.7	2.260	1,603	760											
		08/16/72				6.9	1.900	1,504	640											
		09/13/72				7.1	1.570	1,226	640											
		10/11/72				7.2	1.340	1,197	600											
		11/15/72				6.8	0.840	1,183	740											
		12/18/72				7.7	0.810	1,092	570											
		01/17/73				7.4	0.600	1,144	600											
		02/14/73				7.8	0.570	1,042	520											
		03/13/73				7.7	0.430	1,047	450											
		04/11/73				7.5	0.500	1,096	490											
		05/17/73				7.3	0.500	1,025	440											
		06/12/73				6.8	3.920	1,273	660											
		07/11/73				7.4	3.000	1,335	610											
		08/14/73				7.5	1.650	1,321	650											
		09/11/73				7.6	0.940	1,122	530											
		10/16/73				7.3	0.590	1,057	450											
		11/12/73				7.2	0.450	1,032	420											
		12/13/73				7.5	0.570	1,075	360											
		01/17/74				7.7	0.320	1,017	470											
		02/20/74				7.8	0.290	954	380											
		03/13/74				8.4	0.140	950	350											
		04/11/74				8.0	0.100	820	330											
		05/16/74				6.6	0.010	702	320											
		06/12/74				8.2	0.040	919	500				287							
		07/18/74				7.5	0.020	1,150	410				547							
		08/12/74				8.1	0.020	722	340											
		09/12/74				7.4	0.030	874	340											
		10/16/74				7.3	0.010	788	320				465							
		11/20/74				7.2	0.010	722	210											
		12/17/74				7.2	0.050	708	180											
		01/17/75				7.3	0.010	746	340				629							
		02/20/75				6.9	0.010	704	320											
		03/13/75				7.3	0.010	728	290											
		04/16/75		753		7.4	0.010	1,134	270											
		05/14/75		770		7.0	0.010	890	270					0.01						
		07/23/75		1,828		6.2	0.020	972	362					0.04						
		08/13/75		825		7.1	0.010	1,022	345					0.02						
		09/23/75		874		7.0	0.020	788	323					0.73						
		10/16/75		824		7.0	0.020	780	298					0.61						
		11/12/75		750		6.7	0.010	788	372					0.57						
		12/09/75		690		7.4	0.010	726	362					0.55						
		01/16/76		730		7.0	0.010	794	612					0.02						
		04/15/76		750		7.5	0.010	770	275	35				0.02						
		06/29/76		907		7.8	0.020	762	242	29				0.62						
		10/14/76		831			0.020	726	283	27				0.42						
		01/10/77		1,030		6.8	0.050	1,370	627	40				1.10						
		04/18/77		740		8.2	0.020	776	307	20				0.51						
		05/24/77		780		8.1	0.010	818	281	30										
		05/27/77		770		8.5	0.010	928	280	29				0.74						
		05/31/77		770		8.1	0.010	902	280	35				0.82						
		07/26/77		830	14.9	8.0	0.020	704	305					0.73						
		01/12/78		770	13.8	7.7	0.010	714	283	26	49	0.3								
		04/05/78		630	11.6	8.1	0.120	774	261	40	41	0.4								
		08/22/78		920	14.0	7.2	0.020	848	324	30	51	0.2								
		10/19/78		820	14.8	7.3	0.010	842	258	26	47	0.2								
		01/11/79		820	14.2	7.1	0.010	792	306	132	50	-0.1								
		05/17/79		830	14.7	7.3	0.020	786	263	33	46	0.1								

Table 12f

water quality data supplied by kennecott copper corp.

Well #	Location	Date	Depth	Cond.	Temperature (C^o)	Milligrams/Liter														
						PH	CU	TDS	SO_4	Cl	Mg	Al	Hardness	Fe	Na	K	Ca	HCO_3	CO_3	
S-53	12 aac	07/11/79		680	15.5	7.3	0.020	768	273	30	54	0.1								
		08/14/80			19.5	7.2	0.050	868	433	32	47	0.2		0.17						
		11/03/80		900	15.0	7.0	-0.010	804	318	28	48	-0.1		0.05						
		11/21/80		850	10.0	7.1	-0.010	822	361	10				0.22	21					0
		11/24/80		850	13.5	7.0	-0.010	824	360	13				0.15	122					0
		12/04/80		850	10.0	7.1	0.010	836	346	14				0.23	25					0
		12/09/80		825	13.0	7.1	-0.010	852	349	40				0.19	28					0
		12/15/80		850	14.0	7.0	0.020	786	334	36				0.22	28					0
		12/23/80		950	15.0	6.6	0.020	762	388	38				0.16	21					0
		12/29/80		850	14.5	6.9	0.010	846	347	40				0.17	25					0
		01/06/81		830	13.5	7.1	-0.010	794	400	21				0.25	22					0
		01/12/81		980	15.0	7.2	0.010	640	402	31				0.13	23					1

Negative numbers indicate less than values.

Table 12g

Dissolved-solids, chloride, and sulfate contents of water from selected wells which exceed the recommended limits for drinking water.
[Chemical data in milligrams per liter]

Well number	Chloride	Sulfate	Dissolved solids	Well number	Chloride	Sulfate	Dissolved solids
(B-1-1)5ddd-1	490	----	1,060	(C-3-1)6dbc-2	260	441	1,240
6cca-1	----	----	567	13bab-1	----	----	908
9aba-1	898	----	1,730	24bcc-1	450	----	1,080
(B-1-2)11dca-4	----	----	612	31aaa-1	----	----	691
(C-1-1)2abc-1	----	----	584	32abb-1	----	----	559
24cdc-2	----	482	1,240	32cdc-1	----	----	519
24dab-18	----	----	664	(C-3-2)5aac-1	----	----	636
24dac-10	----	----	578	5acb-1	----	----	719
24dac-11	----	----	525	34daa-1	----	----	553
24dac-12	----	280	738	(C-4-1)6dad-1	----	319	978
24dad-22	----	264	684	11ccc-1	----	----	825
24dbd-2	----	273	556	22dbd-1	----	----	689
34cdc-2	----	----	798	(D-1-1)4adc-1	----	----	548
(C-1-2)20cbc-1	498	278	1,510	4cac-2	----	----	527
22bcd-4	270	----	856	7abd-6	----	----	644
23cdd-8	312	----	1,170	19bac-4	----	----	609
23ddb-2	280	----	976	19bac-24	----	286	653
23ddc-1	270	----	1,020	19bdc-21	----	264	610
27abc-1	325	338	1,430	19cdb-17	----	----	622
28aaa[1]	412	484	1,730	19dbc-1	----	----	608
28cdd-1	300	373	1,320	20cbc-1	----	262	634
35ada-2	315	----	1,140	20cca-2	----	----	562
36abb-5	280	----	1,020	20ddd-1	----	289	691
36abc-1	298	----	1,110	21ddd-1	----	----	625
(C-2-1)3cdd-4	----	----	661	25ccb-2	----	----	599
14caa-1	315	525	1,430	26bbc-1	----	387	794
32dca-1	----	----	780	(D-2-1)4bcc-1	----	284	642
(C-3-1)4ddd-1	368	579	1,640	17bcc-7	----	----	515
6cac-1	328	----	928	(D-4-1)6bdd-1	----	----	659

[1]Composite of wells (C-1-2)28aaa-4, 28aaa-5, 28aaa-6, and 28aaa-7.

Table 13

(after Hely et al, 1971)

13

Additional ground water quality data is presented in several basic data reports of the USGS. Data for all wells in the vicinity of the study area is presented in Table 14 (Iorns, Mower and Horr, 1966a, 1966b, Hely, Mower and Horr, 1967).

Analysis of water well data from these USGS publications indicates that all samples taken in the study area have constituent levels below the Utah drinking water standards. Utah has established a higher limit for both TDS and sulfate compared to the National Primary and Secondary Drinking Water Standards. This national standard (40 CFR part 143; Federal Register March 31, 1977) and Federal Register, Dec. 24, 1975) establishes as a primary standard 250 mg/l for sulfate and as a secondary standard, TDS at 500 mg/l. Utah has set a limit of 500 mg/l for sulfate, and 2000 mg/l for TDS.

Water from Butterfield tunnel was sampled by the USGS (Iorns, Mower and Horr, 1966, p. 21) and as can be seen in Table 2, dissolved solids was at 1,340 mg/l, with SO_4 at 877 mg/l in 1975. The values for these constituents at this site have dropped substantially since then. Data from samples taken by BLM at the portal in August, 1981, show TDS of 788 mg/l and SO_4 of 320 mg/l. Downstream, TDS and SO_4 are diluted to 702 mg/l and 277 mg/l, respectively. These values are below the Utah MCL/s for both constituents, but are above the "preferred" limits and the 1962 USPHS recommendation.

Other Constituents

For calcium and magnesium, there is no limit established in the 1962 USPHS standards, and none in the National Primary or Secondary Standards of 1975. However, for calcium, the WHO International Standards of 1958 set a "permissible limit" of 75 mg/l, and an "excessive limit" of 200 mg/l. For magnesium, the 1962 USPHS standards did not contain a limit. The WHO International Standards (1958) set a "permissible limit" of 50 mg/l and an "excessive limit" of 250 mg/l. In the samples taken in the study area from both the USGS and Kennecott, the values are within these guidelines. (The same values for calcium are slightly over the WHO International guideline, but are so only slightly, and could be within the margin of error for lab accuracy).

Sodium and potassium do not have limits set in the 1962 USPHS drinking water standards, nor in the 1972 NAS study, and are not addressed in the 1975 National Interim Standards. However, all values noted in this study area are below recommendations established by other researchers (McKee and Wolf, 1963).

Bicarbonate has the same situation as for sodium and potassium, in that no USPHS standard or National Interim Standard exists. Values seen in the data are all well below recommendations set by other research.

CHEMICAL ANALYSES OF SELECTED WELLS AND SPRINGS IN THE VICINITY OF THE NEVADA TRACT

Well or Spring Number	Date of Collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Na + K: Sodium (Na)	Na + K: Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids 1/	Hardness as $CaCO_3$	Noncarbonate Hardness as $CaCO_3$	Percent Sodium	Sodium Absorption Ratio (SAR)	Specific Conductance (micromhos/cm at 25°C)	pH	Analysis 2/
(C-3-2)																					
5aac-1	1- 45	-	61	.18	86	35	-	-	-	13	142	-	1.2	6/ 636	359	-	-	-	-	7.1	DH
5acb-1	1- 45	-	61	.13	83	32	-	-	-	21	134	-	2.4	6/ 719	[illegible]	-	-	-	-	7.8	DH
5adb-1	7- 46	-	25	-	89	1.4	101		-	21	144	-	-	6/ 686	230	-	-	-	-	8.3	DH
26ccc-1	8- 58	54	33	-	205	53	78		366	261	220	-	19	1,050	728	428	19	1.3	1,640	7.8	GS
26ccc-1	7- 65	54	32	-	215	52	69	-	351	293	208	-	14	1,060	748	460	17	1.1	1,660	7.5	
33cac-1	7- 65	58	35	-	156	44	26	-	304	236	94	-	.6	785	570	321	9	.5	1,130	7.6	
34daa-1 33/	5- 55	-	24	.03	110	32	36	2.1	297	127	74	.0	1.5	553	406	162	16	.8	877	7.6	GS
34dbd-1	7- 65	49	20	-	160	51	30	-	236	387	56	-	.4	830	610	416	10	.5	1,170	7.6	--
35bdc-1	8- 54	-	22	5/ .04	229	37	63		316	128	329	.2	7.6	6/ 1,140	726	467	-	-	-	7.4	DH
35bdc-1	8- 58	54	32	-	236	69	58		326	158	395	-	14	1,120	874	607	13	.9	1,940	7.6	GS
35abc-1	7- 65	56	31	-	231	50	46	-	323	183	292	-	17	1,010	780	515	11	.7	1,710	7.7	
35bdc-1	7- 65	54	30	-	216	15	124	-	326	158	302	-	14	1,020	600	337	13	2.2	1,720	7.5	
26ccc-1	7- 64	54	31	-	204	61	78	-	364	290	225	-	15	1,210	760	461	18	1.2	1,650	7.5	
33cac-1	7- 64	58	33	-	148	41	44	-	308	242	92		2.5	798	540	287	15	.8	1,110	7.4	
35abc-1	7- 64	56	31	-	228	49	77	-	328	171	340	-	13	1,410	770	501	18	1.2	1,730	7.4	
35bdc-1	7- 64	54	30	-	204	56	87	-	326	152	350	-	13	1,330	740	473	20	1.4	1,710	7.8	
31 cd	8- 81		21	-	192	65	71	2	402	405	120	.32	3.25	1,168	745	330			1,620	7.2	
(C-4-3)																					
2db	8- 81		22		216	74	49	3	286	680	40	.86	.10	1,290	845	235			1,580		
12ad	8- 81		19		136	46	21	2	276	320	28	.48	.06	788	530	226			1,006		

1/ Dissolved solids are calculated from determined constituents except as noted.
2/ Analysis by: OH. Utah State Department of Health
GS. U.S. Geological Survey
5/ Iron (Fe) in solution at time of collection.
6/ Residue on evaporation.
33/ Includes .02 ppm boron (B) and .10 ppm manganese (Mn).

Table 14

Chloride has a limit of 250 mg/l set in the 1962 USPHS standards and is the same in the NAS Study of 1972. Values from Kennecott data are all below this standard, except for one sample point, W-131. The 250 mg/l limit was exceeded in one sample taken in 1967. This is not very conclusive since only one sample was taken during that year, and other samples showed values below the 1962 USPHS standard.

Magnesium values reviewed are not high on their own merit, but when combined with high SO_4 content, they become significant according to 1961 WHO standards. High Mg values were noted in stations W-18, S-22A, W-130, S-53 and W-41.

Values for iron are all below the 1962 USPHS standards.

Values for fluoride from USGS are below the 1962 USPHS standard and the 1972 NAS study recommendations.

Values for nitrate are below the 1962 USPHS standards; however, the 1972 NAS Study lowered the USPHS standard to 10 mg/l. Some wells show values for nitrate above this limit. These sources, however, are well away from the mountain front, and probably reflect contamination due to use of fertilizers for farming in the area. The NO_3 value should not be affected at all by the mining activity, or the expansion of waste dumps.

Historical ground water quality data are also found in Marine (1960), and presented in Table 14 (for wells in study area). Additional drinking water analyses are found in Appendix 1 (Bousfield, 1981).

With the exception of site S-21B, none of the data reviewed in this study indicated a serious level of contaminants. Many values are above standards set by other entities, but are still below the Utah Maximum contaminant levels (MCL's). The impacts to drinking water in the area have not been serious, but the values are or have been moving upwards towards the MCL levels, although many analyses have shown a slow but continual downward trend.

Many standards discussed have been set based on taste considerations more than health hazards. Constituents like arsenic did not show up as a hazard in any of the data made available for this study.

Conclusions and Recommendations

The review of all available data relating to water quality and quantity in the area of proposed mine dump expansion indicates that no detrimental effects are likely to occur if there is no active leaching of the mine dumps with acid.

This study relied heavily on existing data. Field investigation was at the reconnaissance level to determine such things as the principal hydrogeologic units, areas of recharge and discharge, and direction of ground water

movement, but excluded drilling activity to establish new data sites. A few historical records and several short-term monitoring records are available relating to water quality in the vicinity down-gradient from the mine dump area. These data show that water quality has likely been affected by mining activity in the area, but that the effects have been minimal, and have not caused ground water to be contaminated to levels above the Utah maximum contaminant levels (MCL).

However, some constituents exceeded standards set or recommendations made by other entities (e.g., U.S. Public Health Service, World Health Organization (WHO) of the United Nations, or the National Academy of Sciences). For example, the two indicators of leaching used here, SO_4 and TDS, display concentrations in a "transition zone" between other standards and the Utah MCL's. With respect to the Utah standards, although the MCL for sulfate is 1000 mg/l, the preferred limit is 500 mg/liter, and the Utah water quality regulations require that:

> If a sulfate level of a community water system is greater than 500 mg/liter, the supplier must satisfactorily demonstrate that:
>
> 1. No better water quality is available, and
> 2. The water shall not be used for human consumption from commercial establishments.
>
> In no case shall the committee allow the use of water having sulfate level greater than 1000 mg/liter.

Another significant departure from other standards exists with respect to TDS levels. The Utah MCL is 2000 mg/liter; however, at values of 1000 mg/liter the State Department of Health begins to have some enforcement authority. Chapter 3 of the water quality regulations requires:

> (3.1.1a) (at note 3) If a TDS is greater than 1000 mg/liter the supplier shall satisfactorily demonstrate no better water is available. The committee shall not allow the use of an inferior source of water if a better source of water (i.e. lower in TDS) is available.

This is important to note here because many of the values for SO_4 and TDS found in this study are above the "preferred limits", but are below the Utah MCL's. This results in a situation where several sources are now in the "marginal" category (i.e. 1000-1500 mg/l for TDS and 500-1000 for SO_4) for drinking water, and cannot deteriorate much more before loss of use would occur.

Based on the analysis of leaching of the overburden dumps due to natural precipitation, indications are that metals will not be carried into the ground water system. This is due to the chemical action of the limestone that causes precipitation out of solution of the metals. There is such a preponderance of limestone in the overburden dumps that a substantial excess capacity for forming precipitates probably exists. It is probable

that this excess capacity would provide the needed control of leaching over time. It is doubtful that this would hold true if acid was applied to the dumps in a commercial leaching operation. The high content of $CaCO_3$ is seen in almost every analysis reviewed in this study. Typical ranges of values are from 300 to 780 mg/l. This is very hard water indeed, and demonstrates the active solution of the limestone in the ground water system.

The long-term effects of natural leaching are not likely to change substantially from the present situation. The excess precipitation capability of the dumps combined with the small amount of water moving through the dumps are strong mitigating factors that will control the system chemically. Concomitantly, the current and historical data show that values of TDS and SO_4 are maintaining a flat trend line, with some actually decreasing over time.

Natural groundwater in arid regions generally exhibit pH values in the range 6.0 to 9.0. The upper limit usually established by the reaction of carbon dioxide gas and the reactions of limestone or caliche in the soil. The lower limit is an estimate based on expected values of water in non-reactive rocks, such as quartz sandstone (Runnells, 1976, pg. 376). Studies of ground water samples in Arizona by Trost (1974) and reported by Runnels (1976) found a range in pH of 6.0 to 9.0.

If water at the Butterfield Canyon site is of a pH at 6.0 or more, we would not expect serious consequneces of drastic chemical reactions. Water samples taken by BLM personnel in July 1981 all showed pH values in the range 7.0 to 7.7. The data provided by Kennecott for the sites K-69, K-71, W-130, W-131, W-132, W-18, S-22A, W-412, S-21B, S-21A, S-40, S-53, and W-126 all showed pH values in the range 6.2 to 8.7. Data from the Utah Dept. of Health relating to pH showed that all samples had pH in the range 6.9 to 8.5. One sample showed a pH of 9.0.

Unless the system as we now see it performing experiences a stress that the buffering capacity can not accomodate, the system should remain in a fairly constant state of equilibrium.

The impacts to ground water quality with the exchange will very likely be about the same as those occurring without the exchange. Some factors to consider in each scenario are:

With Exchange

1. Waste dump will be thinner, and of greater areal extent.

2. Water flow "transit time" will be shorter, which may decrease the amount of metals leached.

3. Because of the thinner waste piles, oxygen may be more available to the system to drive the oxidation process (described in an earlier section of this report) resulting in greater amounts of metals going into solution.

4. Greater surface area of dumps exposed to precipitation, which potentially could increase the amount of constituents leached.

Without Exchange

1. Waste dumps will be thicker.

2. Because of great dump thickness, the "transit time" will likely be slow, possibly resulting in greater concentrations of metals leached.

3. This thickness, however, will inhibit the formation of oxidation reactions and inhibit the oxidation process.

Dump leaching is a process that is not yet fully understood, even in commercial operations for recovery of copper using acid. Factors such as the size and height of the dumps, the size of crushed or broken rock placed in the dump, the kinetics of leaching and factors that influence solution percolation are some of the factors yet to be defined precisely (Rampacek and Dunham, 1976, p. 46). These factors become even less understood in situations of very low reaction rates involved in natural leaching. Intuitively, the various reaction rates and leaching mechanisms involved in natural leaching should be less sensitive to variables of the kind mentioned above for acid leaching. Suggestive evidence indicates that the primary controlling factor for natural leaching is the amount of $CaCO_3$ available in the dump. Based on Kennecott's projection of increased limestone content of the dumps, the future buffering capacity of the dumps should be more than capable of handling any slight lowering in pH of rainfall, or the induced lowering of pH due to the oxidation reaction of sulfides that generates sulfuric acid.

The direction of ground water flow will be unaffected by the proposed action. Water will continue to recharge the Jordan Valley aquifer at a rate dependant on the annual precipitation in the Oquirrh Mountains, and other factors.

In summary, the incremental effects of expanded mine dumps in the vicinity of Butterfield Canyon will not cause significant large changes in the ground water quality of the down gradient users. The chemical precipitation of metals into insoluble salts should prevent any movement of high concentrations of these constituents into the ground water system.

If acid leaching were to take place (due to changed economic conditions) the potential incremental impacts would then likely become significant, and a more detailed study of geochemical reactions combined with analyses of state-of-the-art mitigation techniques should be completed prior to this new use of the dump area.

As it now stands, the use of the dump sites is not going to change, except for thickness and extent of the dumps, and this increased magnitude of the dumps is not expected to produce significant changes in ground water quality.

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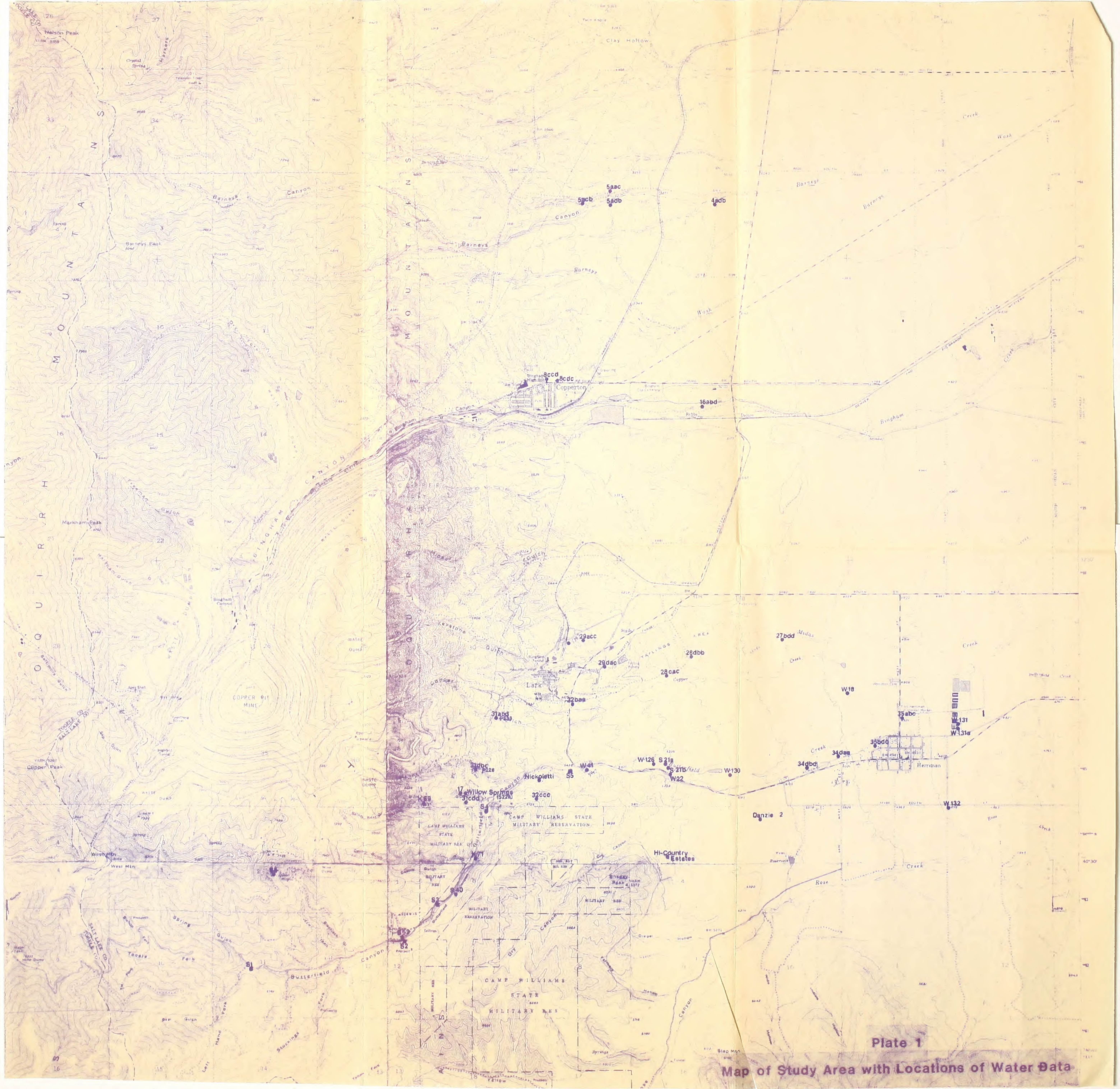

Plate 1

Map of Study Area with Locations of Water Data

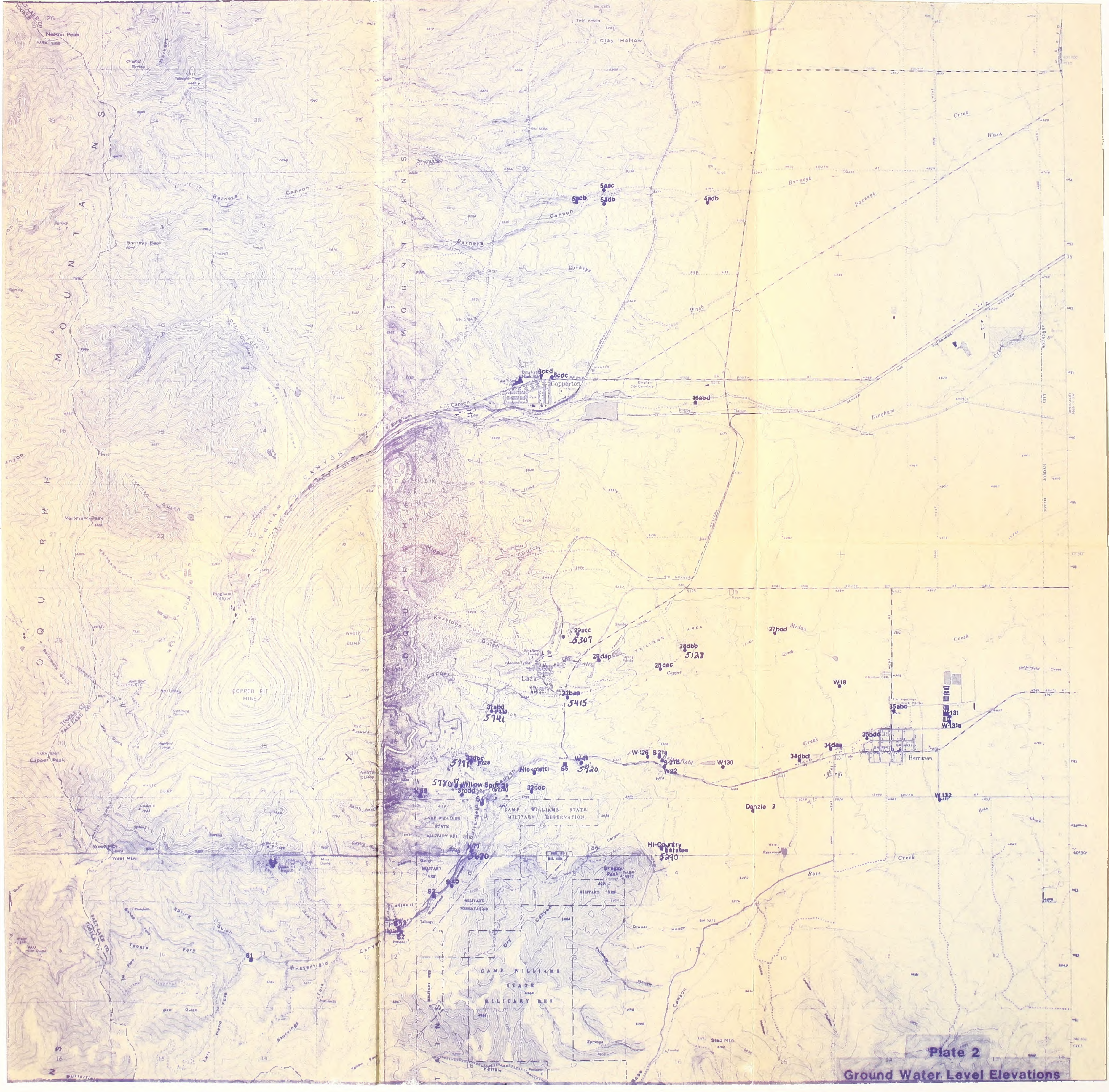

Plate 2
Ground Water Level Elevations